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(71) Applicant: HUNTER INDUSTRIES INCORPORATION [US/US]; 1940 Diamond Street, San Marcos, CA 92069 (US).

(72) Inventors: SCOTT, Mike, R.; 11761 Windcrest Lane, San Diego, CA 92128 (US). RING, James, F.; 2528 San Clemente Terrace, San Diego, CA 92122 (US). CESENA, Antonio, G.; 9565 Vervain Street, San Diego, CA 92129 (US). VAN VLEET, Larry, M.; 2922 Caballista Del Norte, San Clemente, CA 92673 (US). HALE, John, D.; 7047 Camino De Grazia #190, San Diego, CA 92111 (US). McDONALD, Michael, S.; 1575 Tanglewood Lane #1236, Escondido, CA 92029 (US).

(74) Agent: JESTER, Michael, H.; Law Offices of Michael H. Jester, Suite 2560, 750 B Street, San Diego, CA 92101-8122 (US).

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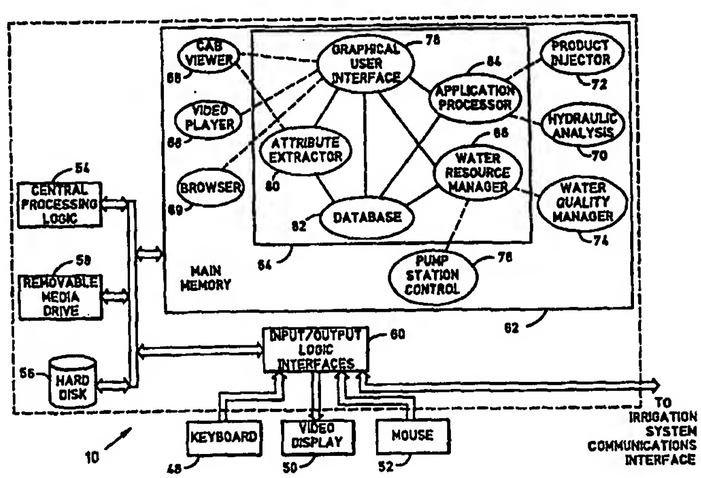

(57) Abstract

A computer-controlled irrigation system, computer program product, and computer-implemented method of operation includes a site map-based graphical user interface (GUI). The GUI includes animations and hyperlinked irrigation system elements that allow a user to traverse the site, zoom in on an irrigation system element or water resource element and adjust its programming parameters or monitor its operation by selecting it with a mouse button click or similar selection mechanism. Graphics representing the site, irrigation system elements and water resource management elements, as well as hydraulic attributes and other attributes describing the functions of such elements may be extracted from a conventional CAD drawing file. The invention may also promote efficient use of water resources by performing hydraulic simulation of the irrigation network using a hydraulic analysis software engine. Hydraulic analysis also maximizes irrigation in accordance with priorities selected by the user. Hydraulic analysis also optimizes product injection by taking loading and other factors into account.

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IRRIGATION AND WATER RESOURCE MANAGEMENT SYSTEM

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to computer-controlled irrigation control systems of the type used in golf courses, master planned housing developments, cemeteries, parks and the like.

Description of the Related Art

Irrigation system controllers allow a user to program the system to irrigate specified zones of a golf course or similar site for specified time periods or until specified volumes of water have been applied. Such conventional systems are difficult for a user to program. Typically, a system may display configuration and programming information in a tabular format on the computer screen, and the user enters information in a tabular format. Elements of the irrigation system, such as pumps, valves and irrigation heads are designated by numeric or alphanumeric labels. The various pipes of the irrigation network may be designated by labels or by graphical formats that indicate their location in the hierarchy of main supply pipes branching into smaller pipes. For example, the display may indicate by means of a label "1st Hole" indented slightly to the right and below a label "2 Inch Branch," which is in turn indented slightly to the right and below a label "10 Inch Main," that the irrigation heads in the zone relating to the first hole of the golf course are supplied by a certain two-inch branch pipe that is in turn supplied by a certain ten-inch main pipe.

Computer-controlled irrigation systems for golf courses have been developed that include graphical user interfaces (GUIs). The GUI may display a map of the site on the computer screen. The site map indicates the fairways, greens, tees, roughs, bunkers and lakes and other features, as well as the locations of pipes and irrigation heads in relation to those features. In operation, the system graphically indicates which heads are in use and which are not, and may also indicate other pertinent information. To set up such systems prior to use, the user must enter the site map in the form of a suitable digital image. Once the site map has been entered into the system, the system prompts the user to enter the positions of the irrigation heads and pipes.

The term "hydraulic management" in the context of irrigation systems refers generally to controlling irrigation in response to flow rate information. A hydraulic tree is the basis of conventional hydraulic management. A user enters hydraulic tree information into the irrigation system by specifying the connectivity of the network as well as the user's estimate of the maximum flow rate in each pipe. In operation, the system may compute the flow rate at any irrigation head in response to the open or closed status of network valves. The system computes the flow rate along a straight path between the pressure source (typically a pump) and each head. Hydraulic management may be used to facilitate programming the system to apply a specified volume of water to a specified zone by computing the time required to operate certain heads based on the flow rates at those heads.

In reality, a hydraulic system comprising a network of irrigation pipes behaves in a more complex manner than can be modeled by a hydraulic tree. A head or section of pipe may be fed by several pipes that are ultimately coupled together at some point in the network closer to the source. In other words, the network includes loops. Hydraulic management systems that are based upon the hydraulic tree model cannot model loops because they simplify the problem to the computation of flow rate along a straight path.

Hydraulic analysis software programs are used by civil engineers in the design of municipal water supplies, water treatment plants, and similar industrial operations. Examples of commercially available hydraulic analysis programs include KYPIPE, produced by The University of Kentucky, and CYBERNET, produced by Haestad Methods, Inc. of Waterbury, Connecticut. Designers of irrigation systems have also used such programs. Hydraulic analysis programs can model the dynamic behavior of a complete piping network, including loops and other features, and can compute not only flow rate at any pipe section but also water velocity, dynamic pressure, and volume in any pipe section. Furthermore, such programs take into account changes in elevation, turbulent flow, and other real-world conditions.

Irrigation systems have long included product injection units to mix liquid nutrients, i.e., fertilizers, into the irrigation water, a process known as fertigation. More recently, they have been used to apply beneficial microorganisms ("biologics"), pesticides and soil amendment minerals. Injection units are typically operated for a programmed time period or as a ration of measured discharge flow. The injection unit operation is not otherwise coordinated with

irrigation programming. Another challenge of using irrigation systems to distribute products is known as pipe "loading." The piping network between the injection unit and the irrigation head may hold a considerable volume of water. It may be desirable to apply a product, such as a biologic to suppress fungus, yet minimize irrigation volumes to avoid overwatering. Such a scenario is typical during a time of rainfall. If the system is operated for a sufficiently short time to avoid overwatering, the injected product may not reach outlying areas furthest away from the injection unit by the end of the application period.

Golf courses often contain lakes and other bodies of water that serve not only as obstacles to challenge golfers but also as irrigation water reservoirs. Golf courses may include water resource management systems that control the filling of such reservoirs from the water supply and the draining of them into the irrigation system. More sophisticated systems may also include aeration systems in reservoirs to assist in water quality management. Water resource management systems may include various pumps, valves, air compressors and oxygen injectors.

It would be desirable to provide an irrigation control system that enhances ease of programming and monitoring and that includes improved hydraulic management. It would also be desirable to provide an irrigation control system with improved product injection that is coordinated with irrigation programming and that takes loading and other hydraulic factors into account. Furthermore, it would be desirable to provide an improved lake water resource management system that is coordinated with irrigation programming and that is easy to program and monitor. These needs are satisfied by the present invention in the manner described below.

SUMMARY OF THE INVENTION

The present invention relates to a computer-controlled irrigation system, computer program product, and computer-implemented method of operation that includes a site map-based graphical user interface that displays information on the computer screen and receives information input by a user, and an application processor that generates irrigation controller commands in response to the programming information received from the user. The irrigation system itself may include any combination of irrigation heads, valves, pipes, water sources and other elements of the types commonly used in irrigation systems for golf

courses, master planned housing developments, cemeteries, parks, and the like. Many existing irrigation systems of this type are computer-controlled, and can be controlled in accordance with the present invention merely by reprogramming the computer of such a system in accordance with the invention, provided that the computer hardware is sufficiently capable.

The site map may be represented by a computer-aided design (CAD) drawing file produced by any suitable commercially available CAD program. The site map depicts the site, e.g., the landscape architecture of a golf course, and the irrigation system elements such as piping, irrigation heads, zones, pump stations or other elements. The graphical representations of irrigation system elements are logically linked to an object attribute group. Most CAD programs generate drawing files in which the drawing objects may be linked to one or more attributes, and any such CAD program that allows a user to define attributes is suitable. The attributes describe the irrigation system element. For example, an attribute group linked to a depiction of a sprinkler head may include not only those attributes that the CAD program automatically generates, but also additional user-defined attributes such as minimum and maximum operating pressures, nozzle size, flow rate, rotation speed and arc.

The user interface may include a movie player for displaying a movie or video image site map depicting the site from the perspective of a movie or video camera moving through the site. The terms "movie" and "video" are not intended to imply any particular format or standards, but merely reflect that commercially available player software typically refers to such moving images as movies. Perhaps more accurately, they may be referred to as animations. The movie-image site map may be the sole site map or may be included in combination with a more conventional two-dimensional site map. In embodiments of the latter type, a user may switch from one map to the other by making suitable selections.

Any type or grade of graphics is suitable for the site map and other depictions of the site and irrigation system elements. In the illustrated embodiment the depictions range in grade or quality from two-dimensional maps showing little more than the boundaries of greens, fairways, and so forth to three-dimensional renderings of pumps and other elements. Nevertheless, the depictions may be more symbolic and less realistic in other embodiments or may be more realistic, even of photorealistic quality or actually incorporating photographic imagery, in still other embodiments. The term "map" or the term "graphical" is thus not intended to limit the depictions in these respects.

The application processor receives programming parameters that the user inputs. The parameters may include, for example, a selection of the zones to which the user wishes the irrigation system to apply water or other product. In addition, or alternatively, they may include a water application volume that represents the volume of water the user wishes the irrigation system to apply to the site or to a selected zone or zones. In addition, or alternatively, they may include soil percolation information. They may also include, in addition or alternatively, product selections that represent the different products the user wishes the irrigation system to apply, such as water, nutrients and biologics, and in what order the user wishes them to be applied. The user may also provide an overall start time and/or stop time for the applications. The application processor may compute the start and/or stop times of individual product applications in response to the overall start and stop times, the volumes selected, the soil percolation information, programming priorities, and as discussed further below, hydraulic analysis computations in response to these programming parameters.

The application processor may include a hydraulic analysis manager that includes a commercially available hydraulic analysis program of the type used by engineers and other designers of hydraulic systems. In the illustrated embodiment, the CYBERNET program is indicated as a preferred program because it can read AUTOCAD drawing files directly. The hydraulic analysis manager conducts simulations of the piping network in response to the hydraulic attributes of the irrigation system elements provided via the CAD drawing. Nevertheless, other programs would be suitable. The programming parameters may include a priority for the applications that represents the order or precedence among the regions of the site. For example, the user may select a much higher priority for the greens than the roughs to ensure that the greens are watered. The application processor uses the hydraulic analysis manager to conduct simulations to maximize the number of selection regions to irrigate within the capacity of the water source and the limitations of the piping, pumps and other piping network elements. Thus, if the user were to assign a higher priority to the greens than the roughs, the irrigation system would only water the roughs if it were also capable of watering the greens within the selected time period. In contrast to the hydraulic analysis program in the present invention, a conventional hydraulic tree cannot perform such simulations or computations.

The present invention may also include water resource management. that allows a user to monitor and control water resources such as lakes, wells and

other water supplies. The user interface may allow a user to select a body of water or similar water resource depicted on the site map. In response to such a selection, the user interface may provide a more detailed depiction, such as a three-dimensional animation that illustrates the movement of water into or out of the resource or otherwise in association with the resource. By further selecting an element associated with the resource, the user may provide programming parameters that control the resource. For example, a user may select a valve that controls the filling of a lake. The user may make a selection that opens the valve. In response, the invention accordingly generates commands to the water resource system to open the actual physical valve. Moreover, however, the user interface may generate an animation depicting the water beginning to flow out of a discharge pipe into the lake that occurs in response to the opening of the valve. The user interface may also depict the lake level rising or falling via an animation. Not only valves, but also pumps, aerators, ozone generators, product injectors and other water resource elements may be monitored and controlled in such a manner.

The invention may include any of the above-described features by themselves or in any suitable combination. By means of these features and others described below, the invention allows a user to control an irrigation system via an intuitive and easy-to-use user interface and conduct sophisticated hydraulic management. The invention also allows a user to control and monitor water resources using the same concept of an intuitive and easy-to-use user interface.

The foregoing, together with other features and advantages of the present invention, will become more apparent when referring to the following specification, claims, and accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present invention, reference is now made to the following detailed description of the embodiments illustrated in the accompanying drawings, wherein:

Figure 1 is a block diagram of a computer-controlled irrigation and water resource management system;

Figure 2 illustrates a computer programmed in accordance with the invention;

Figure 3 is a flowchart illustrating th overall operation of the system;

Figure 4 illustrates a screen on the computer displaying a site map prior to logging on;

Figure 5A illustrates a window on the computer relating to attribute group editing;

Figure 5B illustrates another window on the computer relating to attribute group editing;

Figure 6 illustrates a screen on the computer displaying a site map after logging on;

Figure 7 illustrates a screen on the computer displaying a site map upon selection of Programming mode;

Figure 8 illustrates a screen on the computer relating master programming of irrigation priorities;

Figure 9 is a flowchart illustrating the Programming mode;

Figure 10 illustrates a screen on the computer relating to selecting zones on a hole basis;

Figure 11 illustrates a screen on the computer relating to selecting zones on a hole sub-group basis;

Figure 12 illustrates a screen on the computer relating to selecting zones on an individual zone basis;

Figure 13 illustrates a screen on the computer displaying a site map relating to Application mode;

Figure 14 is a flowchart illustrating Application mode;

Figure 15 illustrates a further screen on the computer relating to Application mode in which a hole is depicted;

Figure 16 illustrates a still further screen on the computer relating to Application mode in which a zone is depicted;

Figure 17 illustrates a screen on the computer relating to Application mode;

Figure 18 is a flowchart illustrating an iterative hydraulic analysis;

Figure 19 illustrates a screen on the computer displaying a site map relating to Water Resource Management mode;

Figure 20 is a flowchart illustrating Water Resource Management mode;

Figure 21 illustrates a screen on the computer displaying a site map relating to Water Resource Management mode;

Figure 22 illustrates a screen on the computer displaying a perspective view of water resource management elements relating to a reservoir;

Figure 23 illustrates a screen on the computer relating to reservoir status;

Figure 24 illustrates a screen on the computer displaying a reservoir and associated water quality management unit;

Figure 25 illustrates a screen on the computer relating to product injection valves;

Figure 26 illustrates a screen on the computer relating to compressor and ozone generator operation;

Figure 27 illustrates a screen on the computer relating to injection pump operation;

Figure 28 illustrates a screen on the computer relating to pump control;

Figure 29 illustrates a further screen on the computer relating to pump control;

Figure 30 illustrates a screen on the computer relating to pump control time scheduling;

Figure 3 illustrates a screen on the computer relating to event scheduling;

Figure 32 illustrates a screen on the computer relating to event interval timing; and

Figure 33 illustrates a screen on the computer display relating to reservoir level control.

DESCRIPTION OF PREFERRED EMBODIMENTS

1. Irrigation System Elements

As illustrated in Fig. 1, a computer-controlled irrigation and water resource management system includes a computer 10, which communicates with the various electronically controllable and electronically monitorable elements of an irrigation system via an irrigation system communications interface 12 and a water resource system communications interface 23. These elements of the irrigation and water resource system may include any elements commonly included in irrigation and water resource systems for golf courses, master planned housing developments, cemeteries, parks, and the like. They are disposed on the golf course or other site in the locations and manner known in the art, remotely from computer 10 and communications interfaces 12 and 13,

which may be in any convenient location, such as inside the greenskeeper's office of the golf course.

For example, an irrigation system for a golf course typically includes a number of sprinkler heads, some of which may be of the well-known stand-alone type such as sprinkler head 14, and some of which may be of the well-known valve-in-head type such as sprinkler head 16. Some of the sprinkler heads may rotate in a circular pattern as they spray water, others may move in other patterns, and still others may be stationary or even drip-irrigation sprinkler heads. The term "sprinkler head" or "head" is used in this patent specification to include all such devices that distribute irrigation water to the turf, plantings and other vegetation of the site. A valve 18 controls the flow of water to sprinkler head 14. Both sprinkler head 14 and sprinkler head 16 are coupled to lateral piping 20, which is in turn coupled to distribution piping 22. Typically, distribution piping 22 has a larger diameter than lateral piping 20 because a number of smaller-diameter lateral pipes typically branch off from a distribution pipe. The illustrated topography of piping 20 and 22 with respect to each other and the piping network as a whole is intended merely to be generally illustrative of an irrigation system piping network, and is not intended to have other significance. In a complete irrigation system, the piping network comprising numerous distribution pipes, lateral pipes and other pipes may form a hierarchy or tree of pipes of several different diameters. In a golf course, such a piping network may feed hundreds of heads. Such a complete system is not illustrated in this patent specification for purposes of clarity. It should be noted that the heads are typically grouped into zones of one or more heads. Irrigation networks and controllers and the persons who design them typically identify and distinguish different irrigated areas of a site by zones rather than by individual sprinkler heads.

The heads and any valves controlling them may be controlled by satellite units such as satellite units 24 and 26, which are in turn controlled by a multiple-valve controller 28. Valve controller 28 may be located in a central location out on a golf course, and may control many satellite units distributed about the irrigated areas of the golf course. Each satellite unit may control a number of the heads and zones. Heads such as heads 14 and 16 may be controlled by an irrigation system computer, as known in conventional prior irrigation systems. Thus, computer 10 may control the flow of water to heads 14 and 16 (and any other heads in the same zones) by issuing the appropriate commands. The

commands are encoded in any suitable digital or analog format known in the art and transmitted by communications interface 12 by wires or by radio link to valve controller 28. Valve controller 28, like some commercially available valve controllers presently available, can also generate status information that is potentially readable by a computer.

It is known that pumps such as pump 30 may be similarly controlled by a computer via a suitable communications interface such as interface 13. Pump 30 may, for example, be a booster pump for supplying pressurized irrigation water to distribution piping 22. It may receive water from a municipal water supply, a well or a reservoir of some type. Typically, a group of one or more pumps is controlled via a pump controller such as pump controller 32. Communications interface 13 links pump controller 32 to computer 10 in essentially the same manner as communications interface 12 links valve controller 28 to computer 10. In other words, computer 10 may control pump 30 by issuing the commands appropriate to the commercially available pump controller 32. The format of the commands may be readily determined from specifications provided by the manufacturer of pump controller 32. In certain commercially available irrigation systems, valve controller 28 may be of a type that can not only receive commands from computer 10 but can also generate status information readable by a computer. Pump controller 32 can similarly generate status information.

Product injectors such as product injector 34 may also be controlled by an irrigation system computer. Product injector 34 may be any suitable product injector, such as the FERTIGATION UNIT produced by Weircon, Inc. of Arizona. Product injector 34 may inject fertilizers and other nutrients, soil amendments such as calcium or gypsum, beneficial microorganisms ("biologics"), and pesticides. As with respect to the valves, pumps and other illustrated irrigation system elements, product injector 34 is merely intended to be illustrative of a product injector and is not intended to have other significance. A complete irrigation system, which is not illustrated for purposes of clarity, may include several product injectors. It is known that such product injectors may be controlled by an irrigation system computer. Computer 10 may control product injector 34 by issuing the appropriate commands in a manner similar to that in which it may control heads 14 and 16 and pump 30.

The above-described irrigation system elements and the fact that they may be controlled by a computer are well-known in the art, and such computer-

controlled irrigation system elements and their computer-based controllers and communications interfaces, such as communications interface 12, are commercially available from The Toro Company of Riverside, California, Rain Bird Sprinkler Manufacturing Corp. of Glendora, California, and other manufacturers. Communications interface 13 is similar in function to communications interface 12 and is thus similarly within the knowledge and capabilities of persons skilled in the art. The novelty of the present invention relates primarily not to the irrigation system and water resource management system elements that are located out on the golf course or other site, i.e., the hydro-mechanical and electro-mechanical elements themselves, but rather to the novel programming of the system, operation of the programmed system, and software program products by which a user may cause computer 10 to be programmed. In other words, the present invention may be used, for example, to enhance the functionality of pre-existing computer-controlled irrigation systems by re-programming them in accordance with the present invention. Thus, although the present invention may include any suitable computer hardware and irrigation system elements in certain embodiments, it may consist of the program product or method alone in other embodiments. Persons of skill in the art will readily be capable of programming (or reprogramming) a pre-existing computer 10 in view of the teachings in this patent specification.

The present invention also contemplates the novel control or management of water resources in conjunction with an irrigation system. As further illustrated in Fig. 1, the exemplary irrigation system includes a reservoir 36, which may be a lake or similar body of water on a golf course. A pump 38 associated with reservoir 36 has an intake pipe in reservoir 36 and may be activated to pump water from reservoir 36 into distribution piping 22. A pump controller 40, which may be similar to pump controller 32, controls pump 38. Similarly, a valve 42 associated with reservoir 36 has a discharge pipe in reservoir 36 and may be opened to fill reservoir 36 from a suitable source of pressurized water (not shown). A valve controller 44, which may be similar to multiple-valve controller 28, controls valve 42. Computer 10 may control pump 38 and valve 42 by issuing the appropriate commands in a manner similar to that in which it may control pump 30, heads 14 and 16, and product injector 34.

Reservoir 36 also has a water quality unit 46 associated with it. Many types of devices for managing and monitoring the quality of reservoir water are known. As in other water quality units known in the art for use in association with

golf cours lakes and similar bodies of wat r, the exemplary water quality unit 46 includes aeration compressors, ozone generators and chemical or biologic injectors. Nevertheless, water quality units having other features may also be suitable. Water quality unit 46 preferably includes dual compressors and injection pumps to facilitate service without requiring complete shutdown of the water resource management system. Water quality unit 46 also preferably includes weighted tubing on the bottom of reservoir 36 to communicate water and inject the air, ozone, chemicals or biologics. It may further include a refrigeration unit to store the biologics. A suitable water quality unit along these lines is the Lake Water Treatment Unit produced by Eco-Soil, Inc. of San Diego, California. Eco-Soil's U.S. Patent No. 5,314,619 (Runyon) also relates to a water quality unit, noting that it may be computer-controlled. The disclosure of this patent is incorporated herein by reference.

2. Computer

Computer 10 is illustrated in Fig. 2 as programmed in accordance with the present invention. Computer 10 includes, in addition to the hardware and software indicated by the dashed line as being internal or at least integrally associated with the computer, a keyboard 48, a video display 50, and a mouse 52. These elements of computer 10 may be of any suitable type commonly included in personal computer systems or in minicomputer systems. Computer 10 may be a desktop or even a laptop style. Although not illustrated, computer 10 may include a network connection and communicate via a local area network or wide area network with other computers. In this manner, it may function as a server responding to a remotely located client computer at which a user may work. A user may thus use the present invention to control an irrigation system remotely from any location in the world via a suitable wide area network, such as the global super-network commonly known as the Internet.

Computer 10 may be, in all hardware respects, a conventional, commercially available personal computer. In that regard, computer 10 further includes central processing logic 54, which may include a suitable microprocessor central processing unit such as an INTEL PENTIUM and any suitable associated logic, cache memory, interface or support components commonly included in personal computers. Computer 10 also includes a hard disk 56 and a suitable removable-media drive 58, such as a floppy disk drive or CD-ROM drive or other drive for reading a signal-bearing medium. A program

product embodying the invention, such as a floppy disk or CD-ROM disk on which software has been recorded in accordance with the invention, may be inserted into removable-media drive 58 to program computer 10 in accordance with the invention. The software could equivalently be delivered to computer 10 via a network. Computer 10 includes suitable input/output (I/O) logic interfaces 60 for interfacing with keyboard 48, video display 50 and mouse 52 . Although in the illustrated computer 10 the same I/O logic interfaces 60 are used to provide communication via interfaces 12 and 13 as for the other computer peripherals and I/O devices, in other embodiments communications interface 12 or 13 may include a card that plugs into the personal computer bus internally to computer 10. The types and configurations of these computer hardware elements are not critical to the invention and need only be sufficient to run the software processes described below and communicate properly with the irrigation system elements as described below.

Computer 10 also includes a main memory 62 that is conceptually illustrated in Fig. 2 as programmed with software in accordance with the invention. The software may include any suitable elements written in any suitable programming languages. In an exemplary system, much of the software was written in the VISUAL BASIC language, produced by Microsoft Corporation of Redmond, Washington, which enables the programmer to readily take advantage of the windowing and graphical user interface features of the Microsoft WINDOWS, WINDOWS 95, WINDOWS NT or similar operating system shell. The operating system shell itself is not illustrated in Fig. 2, but is installed in the conventional manner, and the software relating to the present invention is run under the operating system in essentially the same manner as a conventional application program. Nevertheless, in view of the teachings otherwise extant in this specification, persons skilled in the art will readily be capable of designing suitable software code in any suitable programming language.

The VISUAL BASIC code or similar code defines the core software 64 of the system. Core software 64 communicates with commercially available software components in a suitable manner, such as via the Microsoft OLE environment. As well-known to persons skilled in the art, OLE facilitates communication between binary code components in a running software system. OLE allows independent software vendors to write software code that accesses the services of certain components of another manufacturer's software products.

OLE comprises a number of object-oriented application programming interface (API) functions that use the Microsoft WIN32 conventions, as well as a large number of component-object model (COM) standard interfaces. Persons skilled in the art will readily understand how to integrate and use these OLE/COM software interfaces to facilitate communication between core software 64 and the commercially available software components. For example, core software 64 communicates with a suitable computer-aided design (CAD) viewer 66, such as the commercially available AUTOCAD WHIP! display driver produced by Autodesk, Inc. The WHIP! display driver is a so-called "plug-in" component that operates in conjunction with a browser to allow a user to pan and zoom on AUTOCAD drawings.

The AUTOCAD WHIP! display driver is preferred because AUTOCAD is the most widely used CAD program in the world as of this writing. Indeed, many golf course designers use AUTOCAD. Thus, many course owners or greenskeepers using the present invention would have ready access to a pre-existing AUTOCAD drawing file representing their course. Nevertheless, any commercially available CAD display driver that allows a user to edit and extend the attributes of a CAD element would be suitable.

Another software component to which core software 64 has access via OLE is a video or movie player 68, such as the 3D STUDIO MAX produced by Autodesk, Inc. The terms "movie" and "video" are not intended to imply any particular graphics standard or signal standard or hardware devices, as software components operating in accordance with any such standards that display depictions of objects in motion, i.e., animations, would be suitable.

Still another software component to which core software 64 has access via OLE is a browser 69, such as the INTERNET EXPLORER produced by Microsoft Corporation or the NETSCAPE NAVIGATOR produced by Netscape Communications Corporation. As well-known in the art, a browser is a product or a component with a user interface that displays hypermedia documents in accordance with the hypertext transfer protocol (HTTP) or similar protocol and issues requests for such hypermedia documents in response to selection of a hyperlink by a user. As noted above, browser 69 may be used in conjunction with CAD viewer 66.

Another software component to which core software 64 has access is a hydraulic analysis engine 70, such as CYBERNET, which is produced by Haestad Methods, Inc. of Waterbury, Connecticut. Hydraulic analysis engine 70

facilitates simulation of complex hydraulic networks, including velocities, pressure and flow volumes at any point in the network. Although CYBERNET is preferred because it includes an interface that allows it to read AUTOCAD drawing files, other hydraulic analysis engines would be suitable.

Other software components to which core software 64 has access include a product injector engine 72, a water quality manager engine 74, and a pump station control engine 76. These engines and associated drivers are available from the manufacturers of the product injection units or water quality units to which they relate. The OLE architecture is conceptually indicated in Fig. 2 by dashed lines connecting the software elements.

Core software 64 includes a graphical user interface 78, an attribute extractor 80, a database 82, an application processor 84 and a water resource manager 86. The functions of these elements are described below in relation to the method of the present invention. In view of the functional descriptions below, persons skilled in the art will be capable of writing suitable software code in a suitable language such as VISUAL BASIC to implement their functions. It should be noted that although these elements are conceptually illustrated in Fig. 2 as separate entities, they may be integrated with one another in the software code in any suitable manner. In other words, their representation in Fig. 2 is not intended to imply that a specific software architecture is advantageous or preferred.

3. Operation — Overall

The overall operation of an exemplary embodiment of the invention is illustrated by the flow chart of Fig. 3. The flow chart illustrates overall operation in the sense that it includes steps that occur both during and prior to use of the system by a greenskeeper or similar site user. Prior to such use, at step 88 a CAD drawing of the golf course or other site is rendered using a suitable CAD program such as AUTOCAD. This drawing is referred to in this patent specification as a type of site map. Although any person having knowledge of the CAD program and having some artistic ability could render the site map, it would most likely be done by someone other than the greenskeeper or other site user, but in any event this person is referred to for convenience in this patent specification as the draftsperson. Indeed, because the site map includes not only landscape features but also irrigation system elements, the engineer or designer of a golf course's irrigation system may augment a CAD drawing

previously r ndered by the golf course's architect by adding the irrigation system elements. Commercially available CAD programs include an overlay or layer feature, by which elements sharing some commonality may be grouped together as a layer. In AUTOCAD, for example, the landscape and other course features may be grouped as a layer, the irrigation system heads may be grouped as another layer, the irrigation system piping may be grouped as still another layer, and controls, valves and electronics may be grouped as yet another layer. Grouping in this manner or a similar manner is advantageous because AUTOCAD allows the layers to be displayed and otherwise manipulated independently.

Although the site map is not displayed on the computer screen or video display 50 (Fig. 2) for viewing by the site user until a later step, the site map may best be described by reference to Fig. 4, which illustrates such a screen display. The exemplary site map illustrated in Fig. 4 depicts a site (a golf course) and irrigation system elements. Fairways of the golf course are represented by fairway graphics 90 comprising shaded regions bounded by lines. Greens and tee areas of the course are represented by greens graphics 92 comprising shaded regions bounded by lines. Other graphics are shown that represent significant plantings or vegetation. Lakes and other bodies of water are represented by reservoir graphics 94 comprising shaded regions bounded by lines. Still other graphics are shown that represent bunkers. Roughs are represented by other graphics. Irrigation system piping, pump stations, valve stations, injection units and other irrigation system elements are represented by yet other graphics, as do piping, pump stations, valve stations, water quality units and other elements associated with reservoirs or other water resources and water features. Roads, buildings and other miscellaneous golf course elements may be represented by corresponding graphics in the same manner. Graphics 90, 92 and 94 and other graphics types representing categories of golf course elements are preferably shaded differently in color or tone from one another to enable the user to more readily distinguish them. Each of these graphics types may be assigned a different layer in the CAD drawing.

Returning to Fig. 3, step 96 relates to defining boundaries of various groups of elements. AUTOCAD provides a "polyline" feature by which a draftsperson may logically group elements together. Acts upon the group affect all elements of the group. Graphically, a polyline is a continuous, closed line. A polyline may be assigned an attribute group. Other CAD programs have a

similar feature, and the term "polyline," which is an AUTOCAD term, is intended to relate to this feature of any such program. In a golf course site map, the draftsperson may draw a polyline around each fairway or each green to delimit it. A polyline around each hole on the golf course may designate the area of influence attributed to that hole. In other words, certain sprinkler heads, irrigation zones, or any other irrigation elements may be associated with a hole in this manner. Thus, a reference to irrigate hole 6 would implicate all irrigation system elements within the hole 6 polyline. Similarly, a reference to activate or monitor an irrigation system element within that polyline would be recognized as being associated with hole 6.

To facilitate editing the attributes of a block, the CAD program may display a window similar to that of the screen display shown in Fig. 5A, in which the user may enter information. An attribute group for a sprinkler head, for example, may include manufacturer name, part, model or series number, a nozzle identification number, a control address, flow rate in gallons per hour, radius of throw, arc, rotation speed in revolutions per minute (RPM), minimum operating pressure and precipitation rate, as indicated in Figs. 5A and 5B., Fig. 5B being a continuation window reached by clicking on the "Next" button 98 of the window graphics. For irrigation system elements, at least one of the attributes should be a hydraulic parameter, such as the flow rate in the sprinkler head example or the diameter in the case of a pipe. The set of attribute labels, such as "MFGR" for manufacturer name, "partmodelseries" for part, model or series, and so forth, may be input as a template. Thus, as an AUTOCAD draftsperson completes the rendering of a graphics element representing an irrigation system element, for example, the draftsperson selects the "Edit Attributes" function, and a window such as that shown in Fig. 5A appears, pre-labeled with attributes in accordance with the template. When the draftsperson has finished editing the attributes of that irrigation system element, he clicks on the "OK" button 100. It should be noted that the draftsperson need not render the site map or input attributes using the same computer as computer 10 (Fig. 2). The CAD drawing file may be produced anywhere on any computer and loaded onto computer 10 via removable media drive 58 (Fig. 2) or loaded via a network connection.

The CAD program inherently logically links the graphics element with its associated attribute group without further operator intervention. Thus, any reference to that element, such as a user clicking on a displayed graphics

element, causes the processing to respond to the attribute group to which the element is linked.

It may also be worth mention that in the exemplary embodiment, all of the software relating to the present invention operates in accordance with the Microsoft WINDOWS standards. Thus, any image displayed on video display 50 is in the form of a window having at least some of the well-recognized graphics elements that characterize these windowing standards. For example, each displayed image has a header bar, such as header bars 102 and 104 labeled "Edit Attributes" in Figs. 5A and 5B, and a close-window button, such as close-window buttons 106 and 108 in Figs. 5A and 5B. Also in accordance with the windowing theme, this patent specification uses the term "clicking" or "click on" something to refer to the act of using mouse 52 (Fig. 2) or similar pointing device to position a cursor over a graphics element and activating one of the buttons mouse or an equivalent device such as a key on keyboard 48. Windowing and the "point-and-click" concept are familiar to all users of personal computers, and the descriptions below assume that even those readers who may not be skilled in the art to which this invention relates possess at least this rudimentary knowledge.

Returning to Fig. 3, at step 110 the draftsperson inputs into the CAD program attributes describing the irrigation system elements and water resource management elements. Nearly all CAD programs inherently assign attributes to various distinct elements in a drawing. For example, a circle may have attributes that include centerpoint coordinates and a radius. Certain CAD programs, such as AUTOCAD, allow one to define new drawing elements by grouping other elements together and to assign a group of user-defined attributes to the resulting user-defined drawing element. AUTOCAD, for example, allows one to define "blocks" that group together drawing elements or other blocks. The term "attribute," like "block," stems from the lexicon of AUTOCAD, but the terms are used more broadly in this patent specification as applying to any suitable CAD program.

The remaining steps of the overall method occur at run-time, i.e., when the site user operates computer 10 as represented by Fig. 2, which may be referred to in conjunction with Fig. 3. At step 112 attribute extractor 80 scans the CAD drawing file and extracts the attributes, and at step 114 stores them in database 82. Database 82 may be any suitable data structure, and need not be a commercially available database management system.

At step 116 the site user interacts with computer 10 via user interface 78, adjusting programming parameters or observing status information relating to the irrigation system and water resource management system. The first screen that user interface 78 displays on video display 50 depicts the site and allows the user to log in to computer 10. Figure 4 is representative of such an initial screen. It includes an image area and a toolbar, as do most of the screen displays described herein. Note that of the toolbar buttons that are displayed, only the "Log On" button 117 is active, and the remaining buttons are inactive. (In accordance with the windowing standards and practices noted above, an active button is indicated by its high-contrast text and icon, and an inactive button is indicated by its low-contrast text and icons. A computer generally does not respond to clicking on inactive buttons.) Thus, the user's only available selection option is button 117. In response to clicking on button 117, a suitable log-in window (not shown) is displayed, and the user may enter a username and password in the conventional manner. If the user logs on successfully, the screen illustrated in Fig. 6 is displayed. A "Log Off" button 120 replaces button 117, and the other buttons become active. These buttons are: "Event Log" button 122; "Water" button 124; "Application" button 126; "Programming" button 128; "Distribution" button 130; "Pumping" button 132; and "SOS" button 134. The last of these, "SOS" button 134 may be used to access the attribute editing screens discussed above with respect to Figs. 5A-B. It is primarily step 116 to which the remaining sections below of this patent specification relate.

Step 118 relates to the generation of the commands that are transmitted to the remotely located elements of the irrigation and water resource system via communications interfaces 12 and 13 (Fig. 1). Nominally, it is application processor 84 that generates the commands, but, as discussed above, the software architecture is not an important aspect of the invention. Unless the site user or other person inputs changes in irrigation system programming parameters as described with respect to one of the above-mentioned steps, during operation the irrigation system commands continue to be issued from time to time in accordance with step 116. As described below with respect to the display of and the user's interaction with the various user interface screen displays, processing may move from step 118 to step 116 while the user inputs changes in irrigation system programming parameters and then resume at step 118 when the user has completed such changes.

4. Operation — Priority and Timing Programming Parameters

In response to the user clicking on "Programming" button 128 of the main screen display illustrated in Fig. 6, user interface 78 alters the toolbar to replace buttons 124, 126, 130 and 132 with a "Back" button 136, a "Master" button 138, and a "Hole" button 140. In response to clicking on "Back" button 136, user interface 78 would display the previously displayed screen. "Master" button 138 relates to irrigation system programming applicable to the entire golf course or other site. "Hole" button 140 relates to irrigation system programming applicable to each hole (in the example of a golf course).

In response to clicking on "Master" button 138, user interface 78 displays the screen illustrated in Fig. 8. In conjunction with the screen illustrated in Fig. 8, reference may be made to the method of operation of the priority programming aspect of the invention illustrated in Fig. 9. Operation begins at step 141 indicating that the user may input master programming selections.

In the screen illustrated in Fig. 8, the toolbar further includes a "Save" button 142 and a "Change" button 144. The screen includes a "Greens Priority" pop-up box 146, a "Fairways Priority" pop-up box 148, a "Tees Priority" pop-up box 150, and a "Roughs Priority" pop-up box 152. Each of these pop-up boxes includes three hole group selection boxes labeled "All", "1-9" and "10-18", denoting all holes of the golf course, holes 1-9 and holes 10-18, respectively. (Of course, whether the golf course has 18 holes as in the illustrated example or some other number is a matter of golf course design and not important to the invention. Indeed, as discussed above, the present invention may be used to control sites that are not even golf courses, such as parks, cemeteries, master-planned housing developments, and the like.)

Tee, fairway and green graphics 154, 156 and 158 are linked by lines to "Tees Priority" pop-up box 150, "Fairways Priority" pop-up box 148, and "Greens Priority" pop-up box 146, respectively. These graphics depict a representative tee, fairway and green associated with a hole, but the depictions are only intended to be conceptual and not representative of any actual hole on the site.

The screen further includes an "Application Schedule" pop-up box 160 consisting of seven buttons labeled with the seven days of the week ("Mon."-"Sun."). The user first clicks on one of these buttons to select the day of the week to which this master programming is to apply. Different master programming can be created for each day of the week.

The screen further includes an "Order of Priority" pop-up box 162 that initially includes eight boxes containing eight priority icons 164, 166, 168, 170, 172, 174, 176 and 178 depicting the numerals "1" though "8", respectively. Pop-up box 162 also includes four boxes containing disablement icons 180.

After selecting a day of the week, the user may drag any or all of priority icons 164, 166, 168, 170, 172, 174, 176 and 178 into the hole group selection boxes of pop-up boxes 146, 148, 150 and 152. (As well-known the lexicon of windowing, "dragging" an icon to a new location refers to moving the cursor over the icon, depressing the mouse button or other selector and holding it down while moving the cursor to the new location. The icon moves with the cursor to the new location.) In the exemplary screen illustrated in Fig. 8, the user has dragged icon 164 (the numeral "1") to the "All" hole group selection box of "Greens Priority" pop-up box 146, has dragged icon 166 (the numeral "2") to the "1-9" hole group selection box of "Fairways Priority" pop-up box 148, has dragged icon 168 (the numeral "3") to the "1-9" hole group selection box of "Roughs Priority" pop-up box 152, has dragged icon 170 (the numeral "4") to the "All" hole group selection box of "Tees Priority" pop-up box 150, has dragged icon 172 (the numeral "5") to the "10-18" hole group selection box of "Fairways Priority" pop-up box 148, and has dragged icon 174 (the numeral "6") to the "10-18" hole group selection box of "Roughs Priority" pop-up box 152. Priority icons 176 and 178 remain in their initial locations in "Order of Priority" pop-up box 162 as do the four disablement icons 180. The user may also select a time at which the irrigation applications are to start, using a "Start Applications" selector box 179, and/or a time at which the irrigation applications are to stop, using a "Complete Applications" selector box 181. If the user is satisfied with these selections, the user may click on "Save" button 142 to save the selections.

The exemplary selected priorities illustrated in Fig. 8 are used in combination with the selected irrigation application parameters and a hydraulic simulation to compute, as discussed in further detail below in the section titled "Operation -- Input of Water and Product Application Parameters." Nevertheless, for purposes of understanding the priority programming aspect of the invention described in this section, the following should be appreciated. The exemplary selected priorities indicate that: all greens of the course are to be afforded the highest priority ("1") and watered with a selected volume (as described below) before using any remaining volume capacity to water other ar as; fairways 1-9 are to be afforded the next lower priority ("2") and watered with a selected

volume so long as all greens can also be watered; roughs 1-9 are to be afforded the next lower priority ("3") and watered with a selected volume so long as all greens and fairways 1-9 can also be watered with their selected volumes; all tees are to be afforded the next lower priority ("4") and watered with a selected volume so long as all greens, fairways 1-9 and roughs 1-9 can also be watered with their selected volumes; fairways 10-18 are to afforded the next lower priority ("5") and watered with a selected volume so long as all greens, fairways 1-8, roughs 1-8 and all tees can also be watered with their selected volumes; and lastly, roughs 10-18 are afforded the lowest of these priorities ("6") and watered with a selected volume only if capacity remains to water them if all of the above-mentioned areas are watered.

Returning to Fig. 7, the user may click on "Hole" button 140. With regard to the method of operation illustrated in Fig. 9, step 182 indicates that the user may input programming selections to enable or disable as a group the irrigation heads associated with the selected hole green, fairway, rough and tee.

This screen display is in a suitable format that allows user interface 78 to respond to the user's selection of a golf course hole by clicking on it. One suitable format is Autodesk, Inc.'s Drawing Web File (DWF). AUTOCAD has the capability of saving a drawing file in DWF, and in the present invention it is preferred that a DWF-format version of the site map be stored in this manner and accessible to user interface 78. User interface 78 displays this DWF-format site map via browser 69. By clicking on the graphics depicting a golf course hole, browser 69 senses the activation of corresponding hyperlinks. As noted above, a CAD viewer 66 such as AUTOCAD WHIP! is a component that supplements browser 69 to add pan, zoom and other CAD drawing manipulation capabilities. In response to the user clicking on any graphics associated with a hole, user interface 78 zooms in on the selected hole, as represented by the exemplary screen illustrated in Fig. 10.

In the screen illustrated in Fig. 10, the toolbar consists of "Log Off" button 120, a "Programming" button 184, an "Application" button 186, "Master" button 138, "Hole" button 140, a "Sub-Group" button 188, a "Zone" button 190, "Save" button 142, and "SOS" button 134. The screen includes suitable graphics representing the hole that the user selected, depicting the tee areas, fairway areas and tee areas with tee graphics 192, fairway graphics 194, and green graphics 196. In that respect, these graphics resemble tee, fairway and green graphics 154, 156 and 158 described above, but they are nonetheless different

because they depict the actual topography of the selected hole. Irrigation heads are indicated by head icons 198 which resemble small circles or dots. The screen also includes "Application Schedule" pop-up box 160, "Start Applications" selector box 179 and "Complete Applications" selector box 181, as described above with regard to Fig. 8. These boxes allow the user to select different hole programming for each day of the week.

The screen further includes a "Green Enable/Disable" checkbox 200, a "Rough Enable/Disable" checkbox 202, a "Fairway Enable/Disable" checkbox 204 and a "Tee Enable/Disable" checkbox 206. Checkboxes are common input structures in windowing environments. In accordance with windowing conventions, when the user clicks on a checkbox, user interface 78 displays a check mark ("✓") in it. The check mark disappears when the user clicks on a checked checkbox. By checking the appropriate box within "Green Enable/Disable" checkbox 200, the user can enable or disable irrigation of all greens of the golf course. Similarly, by checking the appropriate box within "Rough Enable/Disable" checkbox 202, "Fairways Enable/Disable" checkbox 204 and "Tee Enable/Disable" checkbox 206, the user can enable or disable irrigation of those areas of hole as a group. Enabled heads and disabled heads are indicated by a different color or shading of the respective head icons 198 representing them. In Fig. 10, head icons 198 resembling unshaded or open circles represent enabled heads, and head icons 198 resembling shaded or filled-in circles represent disabled heads. When the user is satisfied with this programming, the user may click on "Save" button 142.

It should be noted that the user may switch from the above-described programming view illustrated in Fig. 10 to the application mode (Fig. 17) by clicking on "Application" button 186. Clicking on "Programming" button 184 returns the screen to that which is illustrated in Fig. 10.

In response to clicking on "Sub-Group" button 188, the screen is altered as illustrated in Fig. 11. With regard to the method of operation illustrated in Fig. 9, step 208 indicates that the user may input programming selections to enable or disable the irrigation heads of user-defined sub-groups (or default sub-groups) relating to the selected hole. In addition to the icons, buttons, boxes and other graphics described above with regard to Fig. 10, the screen illustrated in Fig. 11 includes a "Green" sub-group selector box 210, a "Tee" sub-groups selector box 212, a "Fairway" sub-group selector box 214, and a "Rough" sub-group selector box 216. Head icons 198 are grouped within sub-group boundary graphics 218

resembling dashed continuous lines. Until modified by the user, the sub-groups consist of four default sub-groups: heads associated with the tee of that hole, heads associated with the fairway of that hole, heads associated with the roughs of that hole, and heads associated with the green of that hole. As noted above in the section titled "Operation -- Overall", the boundaries of these areas are pre-defined by the polylines or similar elements included in the CAD site map drawing itself.

The user may define a new sub-group or modify one of these default sub-groups by clicking on a "Modify" button 220 on the toolbar. A pop-up box (not shown) prompts the user to select the head icons 198 to be included in the sub-group by clicking on them. The user may also enter a label for a new sub-group. For example, a user may define a new sub-group and label it "Fairway - Dry Spots." When the user has completed this programming, the user clicks on an "OK" button in the pop-up box. In response, a new sub-group boundary graphics 218 is displayed encircling the new sub-group. In the example illustrated in Fig. 11, in addition to the default sub-groups associated with the tee and green areas and labeled"T-1" and "G-1", respectively, the user has split the fairway into sub-groups labeled "F-1", "F-2" and "F-3" and split the roughs into sub-groups labeled "R-1", "R-2" and "R-3".

The user may enable or disable the sub-groups using selector boxes 210, 212, 214 and 216, which display the sub-group labels. Selecting a sub-group label toggles it from the enabled to disabled state or vice versa. The head icons 198 within a sub-group boundary graphics 218 indicate their state as described above with regard to Fig. 10 by the use of color or shading; in the illustrated example, head icons 198 resembling unshaded or open circles represent enabled heads, and head icons 198 resembling shaded or filled-in circles represent disabled heads.

In response to clicking on "Zone" button 190, the screen is altered as illustrated in Fig. 12. With regard to the method of operation illustrated in Fig. 9, step 222 indicates that the user may input programming selections to enable or disable individual zones or irrigation heads relating to the selected hole. (Although in certain irrigation systems, the term zone may refer to more than one head, in the majority of irrigation systems and in this exemplary embodiment, the term zone refers to one head.) In this screen, in response to a user positioning the cursor over a head icon 198, a corresponding coverage radius icon 224 is displayed. Coverage radius icon 224 resembles a circle centered on head icon

198. Also, a small information box 226 is displayed, which provides the label or name associated with that head. The screen includes a "Disabled Zones" pop-up box 228 that displays the labels of all disabled heads or zones. The head icons 198 indicate their state by the use of color or shading; in the illustrated example, head icons 198 resembling unshaded or open circles represent enabled heads, and head icons 198 resembling shaded or filled-in circles represent disabled heads.

5. Operation — Irrigation Application

In response to the user clicking on "Application" button 126 of the main screen display illustrated in Fig. 6, user interface 78 displays the screen illustrated in Fig. 13. The method of operation of the irrigation application aspect of the invention is also described with respect to the flowchart illustrated in Fig. 14. Displaying this screen, which includes a perspective or three-dimensional view of a portion of the golf course, is indicated by step 230. User interface 78 displays this image using the services of movie player 68. (See Fig. 2.) As described above, movie player 68 is a software component that displays an image in a suitable video or movie format. In the case of the screen illustrated in Fig. 13, movie player 68 provides for the display of the golf course from the point of view of a video camera moving or flying through the course from one hole to the next. In other words, the view moves from the tee area of a hole down the fairway to the green area and then on to the tee area of the next hole. The path along which the camera or point-of-view may be considered to move may be defined, for example, by an AUTOCAD polyline that is generated along with the other irrigation system elements at the time the CAD drawing is rendered or annotated. In other embodiments, however, the user may be able to navigate through the golf course in any suitable manner. Preferably, this initial display illustrated in Fig. 13 represents a perspective view of hole 1 of the golf course. The screen also includes a pop-up box 232 that displays a movie-image site map of the course, with each hole designated by a hole icon 234. Preferably, an icon (not shown) indicates to the user that the user may take control of the movie using the mouse. For example, the icon may resemble a helicopter, evoking the theme that the user is flying through the course. The user may, for example, navigate forward through the course by holding down one of the mouse buttons and navigate backward through the course by holding down the other mouse button. Navigating forward through the course, for

example, the movie depicts a representation of hole 1, then hole 2, then hole 3, and so forth. Pop-up box 232 also includes a "Programming" button 242 that transfers processing to the programming aspect of the invention, as described above with respect to Fig. 7, in the same manner as if the user had clicked on "Programming" button 128 of Fig. 7.

The user may click on any of hole icons 234. In response, user interface 78 jumps to the point in the movie at which a representation of that hole is displayed. The point-of-view is from a position behind the first tee of the hole selected. This is indicated by step 244 in Fig. 14. Eventually, the movie reaches an area of the golf course for which the user wishes to adjust application parameters. For example, Fig. 15 illustrates a point in the movie at which a representation of the green area of hole 3 is reached. At that point, the user indicates in a suitable manner, such as by clicking a certain mouse button, that application parameters are to be adjusted. This is indicated by step 246 in Fig. 14. In response, the screen is altered as illustrated in Fig. 16.

As illustrated in Fig. 16, head icons 248 are displayed. The display may be in DWF format or a similar format to respond to clicking on head icons 248. Each head icon 248 represents an actual irrigation head and is depicted in its actual location on the golf course. Positioning the cursor 250 over a head icon 248 causes an information box 252 to be displayed. In the illustrated example, information box 252 indicates that the head has an identification label "101-12" and is a Rain Bird model 700E head. Positioning the cursor 250 over a head icon 248 also causes coverage radius graphics 254 to be displayed. Although a sprinkler head generally has a circular coverage pattern, coverage radius graphics 254 is suitably distorted or elongated from a true circle to convey perspective. If the zone to which that head related includes other heads, coverage radius graphics 254 for those heads are displayed as well. The user may then adjust application parameters for that head or zone by clicking with the mouse.

In response to clicking on a head icon 248 to select a zone or head, user interface 78 displays a screen such as that illustrated in Fig. 17 that relates to the selected zone or head. This screen includes "Water Application" graphics 256, "Biological Application" graphics 258 and "Fertilizer Application" graphics 260. These graphics resemble beaker-like water containers with graduated scales that display the water volume in both inches and number of head rotations. The number of head rotations refers to the number of times the head

rotates. As noted above, head rotation rate and flow rate are two attributes of the head element in the CAD drawing. Thus, the two can be correlated to determine the number of rotations required to apply a certain volume of water. Number of head rotations is a quantity that greenskeepers and similar users can intuitively grasp, whereas volume in inches is often more abstract to such persons. Pointer icons 262 resemble arrows that point to the scales. The user may slide each of pointer icons 262 up or down the corresponding scale by dragging it to select the volume of water, biologic, or fertilizer to be applied to the golf course via the selected head.

Although the screen relates to the selected zone or head, the user can choose to have the same settings apply to other zones. The screen includes a "Master" checkbox 264 and corresponding "Master" pull-down selector box 266, a "Hole" checkbox 268 and corresponding "Hole" pull-down selector box 270, a "Sub-Group" checkbox 272 and corresponding "Sub-Group" pull-down selector box 274, and a "Zone" checkbox 276 and corresponding "Zone" pull-down selector box 278. These selections correspond to the zone selection described above in the section titled "Operation -- Priority and Timing Programming Parameters" with regard to Figs. 10-12, whereby the user may enable or disable zones, sub-groups of zones, zones relating to a certain hole or master groups relating to the entire golf course. A pull-down selector box is an input means commonly included in windowing environments. Clicking on the selector arrow and holding the mouse button down causes the selector display to open and a list of options to be displayed in addition to that which is already displayed (i.e., the default option).

In response to these application settings, application processor 84 (Fig. 2) computes the irrigation intervals, i.e., start times and stop times, necessary to apply the selected volumes of water, biologics or fertilizer to the selected zones. The computation includes hydraulic simulation using the services of hydraulic analysis engine 70. This is indicated by step 280 in Fig. 14.

Application processor 84 uses hydraulic analysis engine 70 to perform a simulation of the irrigation network in operation. As described above, in the exemplary embodiment, hydraulic analysis engine 70 may be CYBERNET, which inherently reads AUTOCAD drawings of hydraulic networks. The attributes extracted from the AUTOCAD drawing provide hydraulic analysis engine 70 with all information necessary to compute the flow rate, velocity and pressure at each zone includ d in the simulation. Application processor 84 can determine

whether the computed flow rates are sufficient to achieve application of the selected volumes of water, biologics or fertilizer, application processor 84 within the selected application interval. (See description above regarding Figs. 10-12.) Application processor 84 can take into account the time needed for the water, biologics or fertilizer to penetrate the soil. A "Soil Infiltration Rate" selector box in the screen display 282 (Fig. 17) allows the user to select a soil type, such as "Compacted Clay". A "Reference Element" selector box 284 allows the user to indicate a representative soil infiltration rate that is used to divide by the total volume of applications to determine the quantity required to insure any individual application does not exceed the soil infiltration rate. Application processor 84 can also determine whether the computed pressure at each zone is sufficient to operate the head or heads because the minimum operating pressure of each head is an attribute.

The flowchart of Fig. 18 illustrates the hydraulic simulation in further detail. The processing is iterative. In an outer loop, successive iterations involve successively lower priority levels. (See description of priority levels above with regard to Fig. 8 in the section titled "Operation -- Priority and Timing Programming Parameters".) In an inner loop, successive iterations involve including a progressively greater number of zones in the simulations. At step 286 application processor 84 sets up a simulation that includes zones within the highest priority level, i.e., priority level "1". On the first iteration, the simulation includes a predetermined minimum number of zones, such as two zones. These zones may be zones that are located nearest the center of the priority group. For example, if fairways are to be afforded priority level "1", the simulation performed in the first iteration may include only zones at the center of each fairway. In each successive iteration thereafter, zones are added to expand the coverage area outwardly from the center of the fairway toward the green and tee areas. As indicated by steps 288 and 290, the results of the simulation are compared to the irrigation network capabilities. When it is determined that adding another zone would be unacceptable, i.e., would cause any zone to be inoperable due to insufficient pressure, would cause any zone to be unable to apply a volume sufficient to achieve the selected application volume, or would cause the simulated applied volume to exceed the volume available from the water source or would exceed electrical power limitations of a valve controller, the simulations are terminated and start and stop times are computed at step 292. As noted above, if adding zones resulted in acceptable operation,

additional zones are included in the simulation on the next iteration as indicated by step 294.

Although not explicitly illustrated in Fig. 18, the iterative hydraulic simulation is performed not only for water but also for biologic and fertilizer or other product. Application processor 84 may perform additional hydraulic analysis specific to biologics and fertilizer to account for loading. That is, the application interval for biologic or fertilizer may be computed in response to the volume capacities and flow rates of the network piping between the product injection unit and the simulated zones. This volume of water must be flushed before the injected product would reach the zones. By taking the volume capacity and flow rate into account, the product application interval may be minimized, and the product may be injected at maximum concentration. With regard to the flowchart of Fig. 14, step 295 indicates this additional analysis.

Referring briefly to Fig. 17, the computed application intervals are displayed by application set graphics 296. Application set graphics 296 include one or more ovals or disks, each somewhat resembling a head coverage pattern viewed in perspective. Each disk represents an application, and more than one application may be necessary to ensure adequate soil penetration. A corresponding "Start Time" is displayed adjacent each disk, along with the resulting "Total Amount" (volume) computed to be applied. The disks may be of different colors or shades to indicate whether it is water, biologic or fertilizer that is to be applied. The user may drag the disks to stack them in any desired order. It may, for example, be advantageous to apply biologics after all water applications to maximize the time the product remains on the turf leaves before being washed into the soil by further irrigation.

At step 298 it is determined whether other enabled zones have been assigned a lower priority level. If so, at step 300 another simulation is set up and conducted that includes the zones assigned that priority level. The processing then returns to step 288 as described above. If not, at step 302 it is determined whether alternate water resource system elements exist, as reflected by the CAD drawing and its attributes. For example, a pump station may include more than one pump. A simulation may be conducted that simulates irrigation in a scenario in which one of the pumps has failed. If the resulting diminished capacity is insufficient to meet the programmed priorities, application processor 84 may compute alternate application sets to account for such a contingency. In conventional water resource systems, if a pump fails, irrigation continues in

accordance with the program, since there is no feedback of the failure to the controller. Irrigation heads may not receive sufficient pressure to operate properly and, as a result, no areas will be irrigated. On contrast, by computing alternate application sets, application processor 84 may enable higher priority areas to be irrigated despite a pump failure or other contingency. When the irrigation system is operating, in response to detection of a pump failure the alternate application program may be used. Application processor 84 can readily detect a pump failure in response to status information received from a pump via pump station control engine 76.

It should be noted that although the exemplary embodiment involves an iterative simulation, those persons skilled in the art may appreciate alternative means for computing hydraulic demands on selected irrigation zones that are not iterative.

When the user is satisfied with the application programming, the user may click on the "Save" button 306 on the toolbar (Fig. 17) to save it. Saving the application programming causes application processor 84 (Fig. 2) to respond by generating the appropriate irrigation system commands at the appropriate times to start and stop the application events in accordance with the programming. The commands are transmitted via communications interfaces 12 and 13 directly to the zones or to the zones via satellite stations. The commands may be in any suitable digital format as specified by the manufacturer of the valve, pump, product injector or other irrigation system element. In the case of commands for a product injection unit, application processor 84 may use the services of product injector engine 72.

In response to clicking on "Event Log" button 122, the user may obtain a listing of events that have occurred. For example, the event log may indicate that a pump started or stopped at a certain time, that a valve opened or closed at a certain time, and similar information.

6. Operation — Water Resource Management

In response to the user clicking on "Water" button 124 of the main screen display illustrated in Fig. 6, user interface 78 displays the screen illustrated in Fig. 19. The method of operation of the water resource management aspect of the invention is also described with respect to the flowchart illustrated in Fig. 20. As with other aspects of the invention that may accessed from the main screen, the water resource management aspect begins with a screen display of a site

map at step 308. This screen display is an a suitable format that allows user interface 78 to respond to the user's selection of water resource elements by clicking on them. One suitable format is Autodesk, Inc.'s Drawing Web File (DWF). AUTOCAD has the capability of saving a drawing file in DWF, and in the present invention it is preferred that a DWF-format version of the site map be stored in this manner and accessible to user interface 78. User interface 78 displays this DWF-format site map via browser 69. By clicking on the graphics depicting water resource system elements such as lakes, pumps, transfer piping and so forth, browser 69 senses the activation of corresponding hyperlinks. As noted above, a CAD viewer 66 such as AUTOCAD WHIP! is a component that supplements browser 69 to add pan, zoom and other CAD drawing manipulation capabilities.

The site map not only depicts the golf course elements and irrigation system elements described above with respect to Fig. 4, but now also depicts water resource elements such as pump stations 310, 312, 313 and 314, and transfer piping 316. Several additional buttons are displayed: a "Back" button 318; a "Zoom In" button 320; a "Zoom Out" button 322; and a "Pan" button 324. In response to clicking on "Back" button 318, user interface 78 displays the previously displayed screen. In response to clicking on "Pan" button 324, user interface 78 enters a mode in which the user may move or pan the site map with respect to the window as a whole. The user may pan the site map by moving the cursor to an area of the window over some point on the site map, pressing and holding down one of the buttons of mouse 52, and moving the cursor while continuing to hold down the mouse button. When the mouse button is released, the image remains in the position to which it was dragged or panned. Although panning is not specifically illustrated in the drawing figures, zooming is illustrated.

In response to the user clicking on "Zoom In" button 320, user interface 78 enters a zoom-in mode. If the user moves the cursor to a point on the site map, clicking the mouse zooms or enlarges the display, centered in the window at that point, as illustrated by Fig. 21. Similarly, though not specifically shown, if the user enters a zoom-out mode by clicking on "Zoom Out" button 322, the site map zooms out and may again represent the full site. Figure 21 depicts the result of zooming in on an area of the site map relating to one of the reservoirs. Pump station graphics 310, 312 and 313, transfer piping graphics 316 representing the piping that carries water pumped from the reservoir, as well as an inlet pipe graphics 326 representing piping that discharges water into the

reservoir are all visible in additional detail. Zooming is preferably not instantaneous, but rather is perceived by the user to occur in a smooth or continuous fashion until the desired magnification level is reached.

As indicated by step 328 (Fig. 20), the user may click on a water resource management element to view its status or adjust related programming parameters. Each water resource management element is tagged with a hyperlink in the DWF-format site map. For example, in response to clicking on the reservoir graphics 94 visible in Fig. 21, which is tagged with a hyperlink, user interface 78 displays a screen depicting a perspective or three-dimensional view of the reservoir, as illustrated in Fig. 22. Perspective pump station graphics 330 and 332 represent pumps and associated machinery in three-dimensional detail. A valve, represented by perspective valve graphics 334, is now visible at the discharge end of the inlet piping. As indicated by step 336 (Fig. 7), this display is animated. Although a patent drawing cannot, of course, convey motion, in the actual screen display the discharge pipe is depicted discharging water into the reservoir, with the perspective water graphics 338 conveying motion to the user. In addition, the actual reservoir level is depicted in this screen display. If the reservoir level were lower, the surface of the reservoir would appear to be lower than the level represented by perspective reservoir graphics 340. Monitoring the status of valves and water levels is performed by pump station control engine 76, water quality manager 74 or other commercially available software component that communicates with a sensor station at the reservoir site. Because communication of such status information is known in the art and can readily be achieved using commercially available packages comprising integrated sensor stations and software components, these elements and their use is not described further in this patent specification. Water resource manager 86 (Fig. 2) communicates with such sensing software and functions as an interface between it and user interface 78. User interface 78, in turn, controls perspective water graphics 338 and perspective reservoir graphics 340.

Pump station graphics 330 or 332 may, for example, represent pump 38 described above with respect to Fig. 1. (Dual pumps are depicted because pumps operating in parallel are commonly used in golf courses to facilitate pumping at a wide range of flow rates. For purposes of describing an embodiment of the invention, however, the number of pumps is not important.) Similarly, perspective valve graphics 334 may represent valve 42 described above with respect to Fig. 1.

As indicated by step 342 (Fig. 20), a user may select any suitable element depicted in the screen display. In the exemplary embodiment, perspective reservoir graphics 340 is selectable in this manner. In response to clicking on perspective reservoir graphics 340, which is tagged with a hyperlink, user interface 78 displays a screen with a "Lake Status" pop-up box 344, as illustrated in Fig. 23. Box 344 may indicate the current fill rate of the reservoir, the current pumping rate out of the reservoir, and the predicted time when the reservoir will be full based on these rates. It may also indicate the water level in the reservoir in a bar-graph format or other format that quantifies the more general water level representation shown in Fig. 22. The box also includes a "Historical Level" button 346 and a "Lake Management Unit" button 348. Clicking on button 346 causes user interface 78 to display suitable graphs or reports (not shown) indicating changes in reservoir level over time. Clicking on button 348 causes user interface 78 to display the screen illustrated in Fig. 24.

The screen illustrated in Fig. 24 includes tubing map graphics 350 depicting the tubing through which water quality unit 46 (Fig. 1) interacts with the reservoir 36. Various sections of aeration and biological injection tubing extend around the reservoir perimeter and also from one end of the reservoir to the other roughly down its middle. As noted above, the locations and functions of such tubing is not important to the inventive aspects of the system, but such background information is nonetheless described in the above-referenced patent incorporated by reference relating to Eco-Soil's CLEAR LAKE product. Water quality unit graphics 352 are also included in the screen display to generally indicate the location of water quality unit 46 with respect to reservoir 36. To the left of tubing map graphics 350 is a depiction of the internal elements of water quality unit 46. The depiction may be characterized as a plan view that is somewhat schematic in nature, with some elements shaded to indicate three-dimensionality. The elements include: two aeration compressors, represented by compressor graphics 354 and 356; two injection pumps, represented by injection pump graphics 358 and 360; two product storage tanks, represented by storage tank graphics 362 and 364; and five injection valves, represented by injection valve graphics 366. As set forth in the above-referenced patent, the storage tanks may be used for chemicals or for biologics and may include refrigeration mechanisms to promote preservation of the biological microorganisms. Preferably, when the user moves the cursor over one of these

graphics, user interface 78 displays a small information box adjacent the graphics that identifies the element by a name, such as "Injection Valve No. 3."

As indicated by step 368 (Fig. 20), the user may adjust programming parameters associated with the water resource management element that is depicted. For example, the user may click on storage tank graphics 362 that represent a chemical storage tank. In response, user interface 78 displays a "Chemical Injection Valves Setup" pop-up box 370, as illustrated in Fig. 25. Pop-up box 370 includes valve buttons 372, 374, 376, 378 and 380. Clicking on one of them activates the timeline graphics 382, which includes injection-start icon 384 and injection-stop icon 386. Injection-start icon 384 and injection-stop icon 386 resemble traffic lights, with the former indicating a green light and the latter indicating a red light. The user may drag icons 384 and 386 to set the times of day at which the valve is opened and closed, respectively, to discharge the product stored in the selected tank into the reservoir during the selected interval. By clicking on the "Schedule" graphics box 388, the user is prompted to select an injection schedule, such as during the interval selected as described above, continuously, or other suitable alternatives. The user may also program ozone injection. Injecting ozone inhibits growth of microorganisms in the tubing and valves. In response to clicking on the "Clean Valves Operation" button 390, the cleaning timeline graphics 392 is activated. Cleaning timeline graphics 392 also includes cleaning-start icon 394 and cleaning-stop icon 396 that resemble green and red traffic lights, respectively. The user may drag cleaning-start icon 394 to set the delay in hours and fractions thereof after the completion of chemical or biological injection until the compressor and ozone generator are activated. Similarly, the user may drag cleaning-stop icon 396 to set the delay in hours and fractions thereof after activation of the compressor and ozone generator until they are to be deactivated.

In addition, returning to the screen display illustrated in Fig. 24, the user may click on compressor graphics 354 or 356. In response, user interface 78 displays a "Compressors Operation" pop-up box 398, as illustrated in Fig. 26. Pop-up box 398 includes compressor timeline graphics 400 with compressor-start graphics 402 and compressor-stop graphics 404. Pop-up box 398 further includes ozone generator timeline graphics 406 with ozone generator-start icon 408 and ozone generator-stop icon 410. Ozone generator timeline graphics 406 are activated when the user checks an "Enabled" checkbox 412. The user may adjust these timeline graphics in the same manner as those described above

with respect to injection and cleaning. It may be noted that pressurized air is necessary to carry the ozone through the tubing, and a compressor must operate while the ozone generator is operating.

Pop-up box 398 further includes an "Alternating" checkbox 414, a "Single" checkbox 416, a "Compressor 1" checkbox 418 and a "Compressor 2" checkbox 420. The user may check checkbox 414 to indicate that Compressor #1 and Compressor #2 (as represented by compressor graphics 354 and 356 in Fig. 24) are to be operated alternately, in accordance with the timeline settings. The user may check checkbox 416 to indicate that only one of the compressors is to be operated. If this checkbox is checked, the user may check one of checkboxes 418 and 420 to select that compressor.

In addition, returning to the screen display illustrated in Fig. 24, the user may click on injection pump graphics 358 or 360. In response, user interface 78 displays an "Injection Pump Operation" pop-up box 422, as illustrated in Fig. 27. Pop-up box 422 includes an "Alternating" checkbox 424, a "Single" checkbox 426, a "Pump 1" checkbox 428 and a "Pump 2" checkbox 430. As with the checkboxes described above, the user may check checkbox 424 to indicate that Pump #1 and Pump #2 (as represented by injection pump graphics 358 and 360 in Fig. 24) are to be operated alternately, in accordance with the timeline settings. The user may check checkbox 426 to indicate that only one of the injection pumps is to be operated. If this checkbox is checked, the user may check one of checkboxes 428 and 430 to select that injection pump.

Returning to the screen display illustrated in Fig. 24, the user may click on graphics representing another water resource management element, as again indicated by step 328 (Fig. 20). The user may, for example, click on valve graphics 366. The user may also return to the site map screen display illustrated in Fig. 21. There, the user may click not on reservoir graphics 94 as in the above-described example, but on some other water resource management element, such as that represented by pump graphics 313. Pump graphics 313 may, for example, represent a well. The site map depicts the well pump being connected to the reservoir by piping, thus indicating that the well is a source of water for filling the reservoir. The user need not rely on such inferences as to the function of various elements, however, because, as noted above, moving the cursor over any element causes a small information box to be displayed that indicates the name of the element, such as the "Well Pump 18" information box 432 illustrated in Fig. 28.

As illustrated in Fig. 28, in response to the user clicking on pump graphics 313 representing the well pump, user interface 78 displays a window 434. Window 434 includes pump animation graphics 436, which represents a pump. If the pump is actually in operation at the time, water moving through the pump is depicted. As noted above, computer 10 determines whether the pump is in operation using the software services provided by pump station control engine 76 (Fig. 2) to query the pump status. Window 434 also includes a "Historical Data" button 438, which may be clicked on to cause suitable graphs or reports (not shown) indicating changes in pump operation over time. Window 434 further includes pump mode selector graphics 440, which provides three mode selections for the pump: "Hand" or manual mode; "Off"; and "Auto" (automatic) mode. The user may click on mode control graphics 440 in a suitable manner to select one of these modes.

In "Hand" mode, On/Off selector graphics 442 is displayed. The user may click on On/Off selector graphics 442 in a suitable manner to select whether the pump is to be turned on or off. As noted above, in response to such a selection, computer 10, using the software services provided by pump station control engine 76 (Fig. 2), immediately computes the appropriate water resource system programming commands to turn the well pump on or off.

In response to selection of "Auto" mode, user interface 78 alters window 434 as illustrated in Fig. 29. Window 434 continues to display pump animation graphics 436, "Historical Data" button 438, and pump mode selector graphics 440. Nevertheless, "On/Off" selector graphics 442 is replaced with two buttons: a "Time Clock" button 444 to adjust pump operation to respond to programmed times, and a "Level Control" button 446 to adjust pump operation to respond to reservoir water level. In response to the user clicking on "Time Clock" button 444, user interface 78 displays the screen illustrated in Fig. 30. In this screen, the toolbar no longer includes pan and zoom buttons but rather now includes a "New" button 448, a "Save" button 450 and a "Delete" button 452. The screen also includes pump timeline graphics 454 that depicts not only the hours of the day as in the timeline graphics described above, but also the sunrise and sunset times. Computer 10 automatically computes the local sunrise and sunset times in response to the latitude and longitude of the site and the date, which may be input at system setup time in response to suitable prompts. As noted above, system setup functions are accessed by clicking on "SOS" button 134. The screen further includes a "Schedule" selection box 456, that presents the options

"Daytime," "Daily," "Interval" and "Custom." These options are initially inactive but become active if the user clicks on "New" button 448 to indicate that a new event is to be programmed.

In response to clicking on "New" button 448, user interface 78 adds to the screen display event boxes, as illustrated in Fig. 31. The exemplary screen illustrated in Fig. 31 represents the result of having clicked on "New" button 448 three times, the first causing event box 458 to be displayed, the second causing event box 460 to be displayed, and the third causing event box 462 to be displayed. Each event box includes a numbered button, such as "Event 1," a Start Time display, and a Stop Time display. Events can be deleted by clicking on the "Delete" button 452 on the toolbar. When the user is satisfied with the event programming, the user may click on the "Save" button 450 on the toolbar to save it. Saving the event programming causes water resource manager 86 (Fig. 2) to respond by generating the appropriate water resource system commands at the appropriate times to start and stop the events in accordance with the programming. Water resource manager 86 may use the services of pump station control engine 76. The commands may transmitted to the pumps or valves via communications interface 12 or 13.

Clicking on one of the numbered event box buttons activates pump timeline graphics 454 and causes event-start icon 464 and event-stop icon 466, which have the traffic light-like appearance described above with respect to other timeline graphics, to be added. As with the other timelines, the user may select the start and stop times by dragging event-start graphics 464 and event-stop graphics 466 to position them on the timeline. The displayed Start Time or Stop Time changes as the user drags the corresponding graphics.

The user may select "Daytime," "Daily," "Interval" and "Custom" event scheduling from "Schedule" selection box 468 by clicking on the selection. If the user selects "Daily" the pump is turned on at the selected start time each day and turned off at the selected stop time each day. Selecting "Daytime" causes event-start graphics 464 to automatically move to the time of sunrise that day and event-stop graphics 466 to automatically move to the time of sunset that day. Selecting "Interval" causes the screen illustrated in Fig. 32 to be displayed. This screen includes calendar graphics 470, depicting the current month on a calendar. The screen also includes a "Select Interval" pull-down selector box 472. Clicking on the selector arrow and holding the mouse button down causes the selector display to open and a list of options to be displayed in addition to

that which is already displayed (i.e., the default option). In Fig. 32, the option "Every three days" is already displayed as an example, but additional options include "Every other day," "Every four days," and so forth. After selecting a scheduling interval, the user clicks on the day of calendar graphics 470 on which the scheduled events are to start. In response to that start date and the selected interval, the days on which the events are to occur become highlighted or displayed in a different color from other days. In the exemplary calendar graphics 470, the 5th, 8th, 11th, 14th, 17th, 20th, 25th, 26th and 29th days of the month of January are displayed, indicating that the event is to occur every three days beginning on the 5th of January. (Preferably, the scheduling is automatically continued into the months that follow the displayed month, for a number of years.) The days that the event has already occurred may be highlighted in a different manner to distinguish them from the days that the event is scheduled to occur but has not yet occurred. The user may cause other months to be displayed by scrolling or in any other suitable manner.

Returning to the screen illustrated in Fig. 29, the user may click on "Level Control" button 446 rather than "Time Clock" button 444. In response to clicking on "Level Control" button 446, the screen illustrated in Fig. 33 is displayed. In this level control mode, computer 10 automatically controls the start and stop timing of the associated pump or valve in accordance with priorities and other parameters that the user selects using this screen, which are as follows. The screen includes reservoir level graphics 474, which resembles a sectional view of a lake bank but is intended to be merely conceptual. Superimposed over this representation is a level gauge showing some normal or reference water level labeled with "0", with a scale of other levels below the reference level labeled with progressively larger negative numbers, representing the number of inches of water below the reference level, and other levels above the reference level labeled with progressively larger positive numbers, representing the number of inches of water above the reference level. The screen also includes a "Fill Start" icon 476 and a "Maximum Draw-down" icon 478. These icons resemble arrows pointing to selected levels on the level gauge. The "Fill Start" icon 476 slides up and down the scale when the user drags it to select the level at which the pump is to begin refilling the reservoir if the reservoir should be drawn down to that level by use of the water for irrigation or by evaporation. As the user drags "Fill Start" icon 476, the number in a "Start fill at:" display 480 changes to correspond to the level to which "Fill Start" icon 476 points. The user may drag "Maximum

Draw-Down" icon 478 in the same manner to select the minimum level the reservoir is to reach. As the user drags "Maximum Draw-Down" icon 478, the number in a "Maximum" display 482 changes to correspond to the level to which "Maximum Draw-Down" icon 478 points.

The screen also includes a "Maximum" time selector 484 with which the user may select the time of day at which the user deems it acceptable for the water level to be at maximum draw-down. Typically, this time would be when the golf course is closed, such as the pre-dawn hours. The screen also includes a "Current Level" display 486 that indicates the current water level of the reservoir and a "Projected Irrigation Volume" display 488 that indicates the projected volume of water that is needed to satisfy the irrigation demands in accordance with the programming. As described above with respect to Figs. 14, 17 and 18 in the section titled "Operation -- Irrigation Application", projected irrigation demands are computed in response to the zones selected for irrigation, the priority levels selected for those zones or groups of zones, and hydraulic analysis of the network. Water resource manager 86 may initiate this computation, which is indicated by step 486 in Fig. 20.

The screen further includes source priority graphics 490 and storage priority graphics 492. Source priority graphics 488 includes boxes into which the user may input a number (in a golf course, the number of the hole nearest the source is preferably used) with which the source is associated. The boxes are grouped into three boxes of highest priority or priority level "1", two boxes of the next lower priority or priority level "2", and one box of the lowest priority or priority level "3". Inputting a number into one of the priority level "1" boxes indicates that the water source associated with that hole number is to be drawn from first. Inputting a number into one of the priority level "2" boxes indicates that the water source associated with that hole number is to be drawn from only if the priority level "1" sources cannot alone meet the demand for the deficit amount. Similarly, inputting a number into one of the priority level "3" boxes indicates that the water source associated with that hole number is to be drawn from only if the priority level "1" and "2" sources cannot meet the demand. In the exemplary screen, the user has selected source number "1" as a priority level "1" source and source number "18" as a priority level "2" source. Source priority graphics also include boxes into which a user can input the numbers of any sources to disable, i.e., that are not to be used. In this example, source number "2" is disabled.

If the computations indicate that the total water volume available from priority level "1" sources will be sufficient to maintain the reservoir at or above the maximum draw-down level by the selected time of day, water resource manager 86 activates the priority level "1" source when the setpoint water level is detected. Water resource manager 86 generates the appropriate water resource system commands at the appropriate times to start and stop the priority level "1" pumps in accordance with the storage water levels. As noted above, water resource manager 86 may use the services of pump station control engine 76. If computations indicate that the total water volume available from priority level "1" sources will be insufficient to maintain the reservoir at or above the maximum draw-down level by the selected time of day, water resource manager 86 computes the water volume deficit, and generates the appropriate water resource system commands at the appropriate times to start and stop the appropriate priority level "2" pumps as well. If the combination of the priority level "1" and "2" sources still does not satisfy the above-described criterion, the priority level "3" sources are drawn upon in the same manner. The above-described source priority method enables a user to draw irrigation water from more economical sources that may be available, e.g., a well, before turning to the less economical sources, e.g., a municipal water supply.

Storage priority graphics 492 includes boxes into which the user may input a number of a reservoir. (Again, in a golf course, the number of the hole nearest the reservoir is preferably used.) Like the source priority boxes, the storage priority boxes are grouped into three boxes of highest priority or priority level "1", two boxes of the next lower priority or priority level "2", and one box of the lowest priority or priority level "3". Inputting a reservoir number into one of the priority level "1" boxes indicates that the water source or reservoir associated with that hole number is to be maintained at its normal or reference level before any priority level "2" or "3" reservoirs. Inputting a reservoir number into one of the priority level "2" boxes indicates that the water source or reservoir associated with that hole number is to be maintained at its normal or reference level before any priority level "3" reservoirs. In the exemplary screen, the user has selected reservoir number "1" as a priority level "1" reservoir and reservoir numbers "17" and "18" as priority level "2" reservoirs. Storage priority graphics also include boxes into which a user may input the numbers of any reservoirs to disable, i.e., that are not to be used for water storage. These preferences may be included in the computations described above by water resource manager 86.

7. Conclusion

The invention enhances the ease of use and flexibility of a computer-controlled irrigation system by including a novel GUI. The GUI includes animations and hyperlinked irrigation system elements that allow a user to traverse the site, zoom in on an irrigation system element or water resource element and adjust its programming parameters or monitor its operation. Graphics representing the site, irrigation system elements and water resource management elements, as well as hydraulic attributes and other attributes describing the functions of such elements may be extracted from a conventional CAD drawing file. The invention may also promote efficient use of water resources by performing hydraulic simulation of the irrigation network. The invention may include a hydraulic analysis software engine that is capable of providing far more hydraulic information than a hydraulic tree, including simulation of dynamic conditions. Hydraulic simulation may be used to maximize irrigation in accordance with priorities selected by the user. Hydraulic analysis also optimizes product injection by taking loading and other factors into account. Although the various features and aspects of the invention are integrated in the exemplary embodiment, other embodiments may include a subset of one or more of these features in any suitable combination.

Other embodiments and modifications of the present invention will occur readily to those of ordinary skill in the art in view of these teachings. Therefore, this invention is to be limited only by the following claims, which include all such other embodiments and modifications when viewed in conjunction with the above specification and accompanying drawings.

WHAT IS CLAIMED IS:

CLAIMS

1. A computer program product for programming an irrigation system having a computer-controlled interface, said computer program product comprising a signal-bearing medium carrying thereon:

a database manager for storing irrigation system information in a database;

an information extractor for extracting attribute information from a computer-aided design drawing file and storing said attribute information in said database, said drawing file digitally representing a site map depicting a site and irrigation system elements, each irrigation system element represented by graphical indicia on said site map logically linked to an object attribute group, said object attribute group comprising at least one object attribute representing hydraulic information describing said irrigation system element;

a user interface for displaying said site map, for detecting selection of said graphical indicia by a user, and for providing a graphical input structure for receiving programming parameters input by a user; and

an application processor for computing irrigation controller commands in response to said programming parameters and for communicating said irrigation controller commands to said interface to control application of water to said site.

2. A computer program product for programming an irrigation system having a computer-controlled interface, said computer program product comprising a signal-bearing medium carrying thereon:

a user interface for displaying a site map depicting a site and irrigation system elements, each irrigation system element represented by graphical indicia on said site map logically linked to an object attribute group, said object attribute group comprising at least one object attribute representing hydraulic information describing said irrigation system element, said user interface further for detecting selection of said graphical indicia by a user and for providing a graphical input structure for receiving programming parameters input by a user, said user interface including a movie player for displaying a movie-image site map depicting said site from the perspective of a camera moving through said site, said user interface detecting selection of graphical indicia in said movie-image site map by a user; and

an application processor for computing irrigation controller commands in response to said programming parameters and for communicating said irrigation controller commands to said interface to control application of water to said site.

3. A computer program product for programming an irrigation system having a computer-controlled interface, said computer program product comprising a signal-bearing medium carrying thereon:

a user interface for displaying a site map depicting a site and irrigation system elements including irrigation zones and for receiving programming parameters input by a user, said programming parameters including selected irrigation zones;

an application processor for computing irrigation controller commands in response to said programming parameters and for communicating said irrigation controller commands to said interface to control application of water to said site; and

said application processor including a hydraulic analysis manager for computing hydraulic demands on said selected irrigation zones by performing an iterative hydraulic simulation of applying water to said site via an increasingly larger set of selected irrigation zones until said hydraulic demands on said set of selected irrigation zones of an iteration reaches a predetermined source capacity, said application processor communicating said irrigation controller commands to said interface to control application of water to said site via said set of selected irrigation zones of said iteration.

4. The computer program product recited in claim 3, wherein:

said programming parameters include a plurality of priority groups ranging in irrigation priority from highest to lowest, each priority group having at least one selected irrigation zone; and

said application processor successively computes irrigation controller commands in response to selected irrigation zones of priority groups of successively lower priority.

5. The computer program product recited in claim 3, wherein:

said application processor further comprises a pump failure manager for receiving status information via said interface generated by a pumping station of said irrigation system;

said application processor computes a set of alternate irrigation controller commands in response to an iterative hydraulic simulation in which failure of a pump station is simulated; and

said application processor communicates said alternate irrigation controller commands to said interface in response to status information indicating failure of said pump station.

6. The computer program product recited in claim 3, wherein:

said application processor computes irrigation controller commands representing an application time period in response to said set of selected irrigation zones of said iteration.

7. The computer program product recited in claim 6, wherein:

said programming parameters further include a water application volume and soil percolation information; and

said application processor computes irrigation controller commands representing an application time period in response to said set of selected irrigation zones of said iteration, said water application volume, and said soil percolation information.

8. The computer program product recited in claim 6, wherein said programming parameters further include a water application volume in units of irrigation head revolutions.

9. A computer program product for programming an irrigation system having a computer-controlled interface, said computer program product comprising a signal-bearing medium carrying thereon:

a user interface for displaying a site map depicting a site and irrigation system elements including irrigation zones and for receiving programming parameters input by a user, said programming parameters including a plurality of selected irrigation zones, a plurality of product selections, and a product application order, said product application order indicating an order of application of each product selection with respect to all other product selections; and

an application processor for computing irrigation controller commands in response to said programming parameters and for communicating said irrigation controller commands to said interface to control application of water to said site,

said application processor computing irrigation controller commands representing an application time period corresponding to each product selection.

10. The computer program product recited in claim 9, wherein:

said application processor includes a hydraulic analysis manager for computing hydraulic demands on said selected irrigation zones by performing an iterative hydraulic simulation of applying water to said site via an increasingly larger set of selected irrigation zones until said hydraulic demands on said set of selected irrigation zones of an iteration reaches a predetermined source capacity, said application processor communicating said irrigation controller commands to said interface to control application of water to said site via said set of selected irrigation zones of said iteration.

11. The computer program product recited in claim 10, wherein:

said user interface displays references to a group of products comprising water, nutrient, and biologic; and

said product selections comprise application volumes for a plurality of products selected from said group of products.

12. The computer program product recited in claim 11, wherein said programming parameters further include a water application volume, a nutrient application volume, and a biologic application volume.

13. The computer program product recited in claim 12, wherein said water application volume, said nutrient application volume, and said biologic application volume are in units of irrigation head revolutions.

14. A computer program product for programming an irrigation system having a computer-controlled interface, said computer program product comprising a signal-bearing medium carrying thereon:

a user interface for displaying a site map depicting a site and irrigation system elements including irrigation zones and for receiving programming parameters input by a user, said programming parameters including selected irrigation zones and a product application volume;

an application processor for computing irrigation controller commands in response to said programming parameters and for communicating said irrigation

controller commands to said interface to control application of water to said site; and

said application processor including a hydraulic analysis manager for computing water velocities in piping between a product injection unit and said selected irrigation zones, computing a travel time for injected product to reach each selected irrigation zone in response to said velocities and in response to lengths of said piping between said product injection unit and said selected irrigation zones, and computing an application time period to inject product in response to said travel time and said product application volume, said application processor computing irrigation controller commands representing said application time period.

15. The computer program product recited in claim 14, wherein said product application volume is selected from the group consisting of nutrient application volume and a biologic application volume.

16. A computer program product for programming an irrigation system having a computer-controlled interface, said computer program product comprising a signal-bearing medium carrying thereon:

a user interface for displaying a site map depicting a site and irrigation system elements including irrigation zones and bodies of water and for receiving programming parameters input by a user, said programming parameters including selection of a body of water, said user interface displaying a three-dimensional animation depicting movement of water associated with said body of water; and

an application processor for computing irrigation controller commands in response to said programming parameters and for communicating said irrigation controller commands to said interface to control application of water to said site.

17. The computer program product recited in claim 16, wherein said movement of water is a change in water level.

18. The computer program product recited in claim 16, wherein said movement of water is a flow of water between said body of water and an end of a pipe.

19. A method performed on a programmed computer for programming an irrigation system having a computer-controlled interface, said method comprising the steps of:

storing irrigation system information in a database;

extracting attribute information from a computer-aided design drawing file and storing said attribute information in said database, said drawing file digitally representing a site map depicting a site and irrigation system elements, each irrigation system element represented by graphical indicia on said site map logically linked to an object attribute group, said object attribute group comprising at least one object attribute representing hydraulic information describing said irrigation system element;

displaying said site map on a display of said computer;

providing a graphical input structure for receiving programming parameters input by a user;

detecting selection of said graphical indicia by a user;

computing irrigation controller commands in response to said programming parameters; and

communicating said irrigation controller commands to said interface to control application of water to said site.

20. A method performed on a programmed computer for programming an irrigation system having a computer-controlled interface, said method comprising the steps of:

displaying a site map depicting a site and irrigation system elements, each irrigation system element represented by graphical indicia on said site map logically linked to an object attribute group, said object attribute group comprising at least one object attribute representing hydraulic information describing said irrigation system element;

detecting selection of said graphical indicia by a user;

providing a graphical input structure for receiving programming parameters input by a user, said user interface including a movie player for displaying a movie-image site map depicting said site from the perspective of a camera moving through said site, said user interface detecting selection of graphical indicia in said movie-image by a user; and

computing irrigation controller commands in response to said programming parameters and for communicating said irrigation controller commands to said interface to control application of water to said site.

21. A method performed on a programmed computer for programming an irrigation system having a computer-controlled interface, said method comprising the steps of:

displaying a site map depicting a site and irrigation system elements including irrigation zones;

receiving programming parameters input by a user, said programming parameters including selected irrigation zones;

computing irrigation controller commands in response to said programming parameters;

communicating said irrigation controller commands to said interface to control application of water to said site; and

computing hydraulic demands on said selected irrigation zones by performing an iterative hydraulic simulation of applying water to said site via an increasingly larger set of selected irrigation zones until said hydraulic demands on said set of selected irrigation zones of an iteration reaches a predetermined source capacity, said communicating step comprising communicating said irrigation controller commands to said interface to control application of water to said site via said set of selected irrigation zones of said iteration.

22. The method recited in claim 21, wherein:

said programming parameters include a plurality of priority groups ranging in irrigation priority from highest to lowest, each priority group having at least one selected irrigation zone; and

said step of computing irrigation controller commands comprises successively computing irrigation controller commands in response to selected irrigation zones of priority groups of successively lower priority.

23. The method recited in claim 21, wherein:

said step of computing irrigation controller commands further comprises receiving status information via said interface generated by a pumping station of said irrigation system;

computing a set of alternate irrigation controller commands in response to an iterative hydraulic simulation in which failure of a pump station is simulated; and

communicating said alternate irrigation controller commands to said interface in response to status information indicating failure of said pump station.

24. The method recited in claim 21, wherein:

said step of computing irrigation controller commands comprises computing irrigation controller commands representing an application time period in response to said set of selected irrigation zones of said iteration.

25. The method recited in claim 24, wherein:

said programming parameters further include a water application volume and soil percolation information; and

said step of computing irrigation controller commands comprises computing irrigation controller commands representing an application time period in response to said set of selected irrigation zones of said iteration, said water application volume, and said soil percolation information.

26. The method recited in claim 24, wherein said programming parameters further include a water application volume in units of irrigation head revolutions.

27. A method performed on a programmed computer for programming an irrigation system having a computer-controlled interface, said method comprising the steps of:

displaying a site map depicting a site and irrigation system elements including irrigation zones;

receiving programming parameters input by a user, said programming parameters including a plurality of selected irrigation zones, a plurality of product selections, and a product application order, said product application order indicating an order of application of each product selection with respect to all other product selections; and

computing irrigation controller commands in response to said programming parameters; and

communicating said irrigation controller commands to said interface to control application of water to said site, said irrigation controller commands representing an application time period corresponding to each product selection.

28. The method recited in claim 27, wherein:

said step of computing irrigation controller commands comprises computing hydraulic demands on said selected irrigation zones by performing an iterative hydraulic simulation of applying water to said site via an increasingly larger set of selected irrigation zones until said hydraulic demands on said set of selected irrigation zones of an iteration reaches a predetermined source capacity, said step of communicating said irrigation controller commands to said interface comprising communicating irrigation controller commands to control application of water to said site via said set of selected irrigation zones of said iteration.

29. The method recited in claim 28, wherein:

said displaying step comprises displaying references to a group of products comprising water, nutrient, and biologic; and

said receiving step comprises receiving product selections comprising application volumes for a plurality of products selected from said group of products.

30. The method recited in claim 29, wherein said programming parameters further include a water application volume, a nutrient application volume, and a biologic application volume.

31. The method recited in claim 30, wherein said water application volume, said nutrient application volume, and said biologic application volume are in units of irrigation head revolutions.

32. A method performed on a programmed computer for programming an irrigation system having a computer-controlled interface, said method comprising the steps of:

displaying a site map depicting a site and irrigation system elements including irrigation zones;

receiving programming parameters input by a user, said programming parameters including selected irrigation zones and a product application volume;

computing irrigation controller commands in response to said programming parameters;

computing water velocities in piping between a product injection unit and said selected irrigation zones, computing a travel time for injected product to reach each selected irrigation zone in response to said velocities and in response to lengths of said piping between said product injection unit and said selected irrigation zones, and computing an application time period to inject product in response to said travel time and said product application volume, said step of computing irrigation controller commands comprising computing irrigation controller commands representing said application time period; and

communicating said irrigation controller commands to said interface to control application of water to said site.

33. The method recited in claim 32, wherein said product application volume is selected from the group consisting of nutrient application volume and a biologic application volume.

34. A method performed on a programmed computer for programming an irrigation system having a computer-controlled interface, said method comprising the steps of:

displaying a site map depicting a site and irrigation system elements including irrigation zones and bodies of water;

receiving programming parameters input by a user, said programming parameters including selection of a body of water;

displaying a three-dimensional animation depicting movement of water associated with said body of water;

computing irrigation controller commands in response to said programming parameters and for communicating said irrigation controller commands to said interface to control application of water to said site; and

communicating said irrigation controller commands to said interface to control application of water to said site.

35. The method recited in claim 34, wherein said movement of water is a change in water level.

36. The method recited in claim 34, wherein said movement of water is a flow of water between said body of water and an end of a pipe.

37. An irrigation system for irrigating a site, comprising:

a pressurized water source;

a plurality of irrigation heads;

a plurality of zones, each zone having an electrically controlled valve for selectably coupling an irrigation head to said pressurized water source;

programmed electronic logic, comprising:

a database manager for storing irrigation system information in a database;

an information extractor for extracting attribute information from a computer-aided design drawing file and storing said attribute information in said database, said drawing file digitally representing a site map depicting a site and irrigation system elements, each irrigation system element represented by graphical indicia on said site map logically linked to an object attribute group, said object attribute group comprising at least one object attribute representing hydraulic information describing said irrigation system element;

a user interface for displaying said site map, for detecting selection of said graphical indicia by a user, and for providing a graphical input structure for receiving programming parameters input by a user; and

an application processor for computing irrigation controller commands in response to said programming parameters and for communicating said irrigation controller commands to said interface to control application of water to said site.

38. An irrigation system for irrigating a site, comprising:

a pressurized water source;

a plurality of irrigation heads;

a plurality of zones, each zone having an electrically controlled valve for selectably coupling an irrigation head to said pressurized water source;

programmed electronic logic, comprising:

a user interface for displaying a site map depicting a site and irrigation system elements, each irrigation system element represented by graphical indicia on said site map logically linked to an object attribute

group, said obj ct attribute group comprising at l ast one object attribute representing hydraulic information describing said irrigation system element, said user interface further for detecting selection of said graphical indicia by a user and for providing a graphical input structure for receiving programming parameters input by a user, said user interface including a movie player for displaying a movie-image site map depicting said site from the perspective of a camera moving through said site, said user interface detecting selection of graphical indicia in said movie-image site map by a user; and

an application processor for computing irrigation controller commands in response to said programming parameters and for communicating said irrigation controller commands to said interface to control application of water to said site.

39. An irrigation system for irrigating a site, comprising:

a pressurized water source;

a plurality of irrigation heads;

a plurality of zones, each zone having an electrically controlled valve for selectably coupling an irrigation head to said pressurized water source;

programmed electronic logic, comprising:

a user interface for displaying a site map depicting a site and irrigation system elements including irrigation zones and for receiving programming parameters input by a user, said programming parameters including selected irrigation zones;

an application processor for computing irrigation controller commands in response to said programming parameters and for communicating said irrigation controller commands to said interface to control application of water to said site; and

said application processor including a hydraulic analysis manager for computing hydraulic demands on said selected irrigation zones by performing an iterative hydraulic simulation of applying water to said site via an increasingly larger set of selected irrigation zones until said hydraulic demands on said set of selected irrigation zones of an iteration reaches a predetermined source capacity, said application processor communicating said irrigation controller commands to said interface to

control application of water to said site via said set of selected irrigation zones of said iteration.

40. The irrigation system recited in claim 39, wherein:

said programming parameters include a plurality of priority groups ranging in irrigation priority from highest to lowest, each priority group having at least one selected irrigation zone; and

said application processor successively computes irrigation controller commands in response to selected irrigation zones of priority groups of successively lower priority.

41. The irrigation system recited in claim 39, wherein:

said application processor further comprises a pump failure manager for receiving status information via said interface generated by a pumping station of said irrigation system;

said application processor computes a set of alternate irrigation controller commands in response to an iterative hydraulic simulation in which failure of a pump station is simulated; and

said application processor communicates said alternate irrigation controller commands to said interface in response to status information indicating failure of said pump station.

42. The irrigation system recited in claim 39, wherein:

said application processor computes irrigation controller commands representing an application time period in response to said set of selected irrigation zones of said iteration.

43. The irrigation system recited in claim 42, wherein:

said programming parameters further include a water application volume and soil percolation information; and

said application processor computes irrigation controller commands representing an application time period in response to said set of selected irrigation zones of said iteration, said water application volume, and said soil percolation information.

44. The irrigation system recited in claim 42, wherein said programming parameters further include a water application volume in units of irrigation head revolutions.

45. An irrigation system for irrigating a site, comprising:

a pressurized water source;

a plurality of irrigation heads;

a plurality of zones, each zone having an electrically controlled valve for selectably coupling an irrigation head to said pressurized water source;

programmed electronic logic, comprising:

a user interface for displaying a site map depicting a site and irrigation system elements including irrigation zones and for receiving programming parameters input by a user, said programming parameters including a plurality of selected irrigation zones, a plurality of product selections, and a product application order, said product application order indicating an order of application of each product selection with respect to all other product selections; and

an application processor for computing irrigation controller commands in response to said programming parameters and for communicating said irrigation controller commands to said interface to control application of water to said site, said application processor computing irrigation controller commands representing an application time period corresponding to each product selection.

46. The irrigation system recited in claim 45, wherein:

said application processor includes a hydraulic analysis manager for computing hydraulic demands on said selected irrigation zones by performing an iterative hydraulic simulation of applying water to said site via an increasingly larger set of selected irrigation zones until said hydraulic demands on said set of selected irrigation zones of an iteration reaches a predetermined source capacity, said application processor communicating said irrigation controller commands to said interface to control application of water to said site via said set of selected irrigation zones of said iteration.

47. The irrigation system recited in claim 46, wherein:

said user interface displays references to a group of products comprising water, nutrient, and biologic; and

said product selections comprise application volumes for a plurality of products selected from said group of products.

48. The irrigation system recited in claim 47, wherein said programming parameters further include a water application volume, a nutrient application volume, and a biologic application volume.

49. The irrigation system recited in claim 48, wherein said water application volume, said nutrient application volume, and said biologic application volume are in units of irrigation head revolutions.

50. An irrigation system for irrigating a site, comprising:

a pressurized water source;

a plurality of irrigation heads;

a plurality of zones, each zone having an electrically controlled valve for selectably coupling an irrigation head to said pressurized water source;

programmed electronic logic, comprising:

a user interface for displaying a site map depicting a site and irrigation system elements including irrigation zones and for receiving programming parameters input by a user, said programming parameters including selected irrigation zones and a product application volume;

an application processor for computing irrigation controller commands in response to said programming parameters and for communicating said irrigation controller commands to said interface to control application of water to said site; and

said application processor including a hydraulic analysis manager for computing water velocities in piping between a product injection unit and said selected irrigation zones, computing a travel time for injected product to reach each selected irrigation zone in response to said velocities and in response to lengths of said piping between said product injection unit and said selected irrigation zones, and computing an application time period to inject product in response to said travel time and said product application volume, said application processor

computing irrigation controller commands representing said application time period.

51. The irrigation system recited in claim 50, wherein said product application volume is selected from the group consisting of nutrient application volume and a biologic application volume.

52. An irrigation system for irrigating a site, comprising:

a pressurized water source;

a plurality of irrigation heads;

a plurality of zones, each zone having an electrically controlled valve for selectably coupling an irrigation head to said pressurized water source;

programmed electronic logic, comprising:

a user interface for displaying a site map depicting a site and irrigation system elements including irrigation zones and bodies of water and for receiving programming parameters input by a user, said programming parameters including selection of a body of water, said user interface displaying a three-dimensional animation depicting movement of water associated with said body of water; and

an application processor for computing irrigation controller commands in response to said programming parameters and for communicating said irrigation controller commands to said interface to control application of water to said site.

53. The irrigation system recited in claim 52, wherein said movement of water is a change in water level.

54. The irrigation system recited in claim 52, wherein said movement of water is a flow of water between said body of water and an end of a pipe.

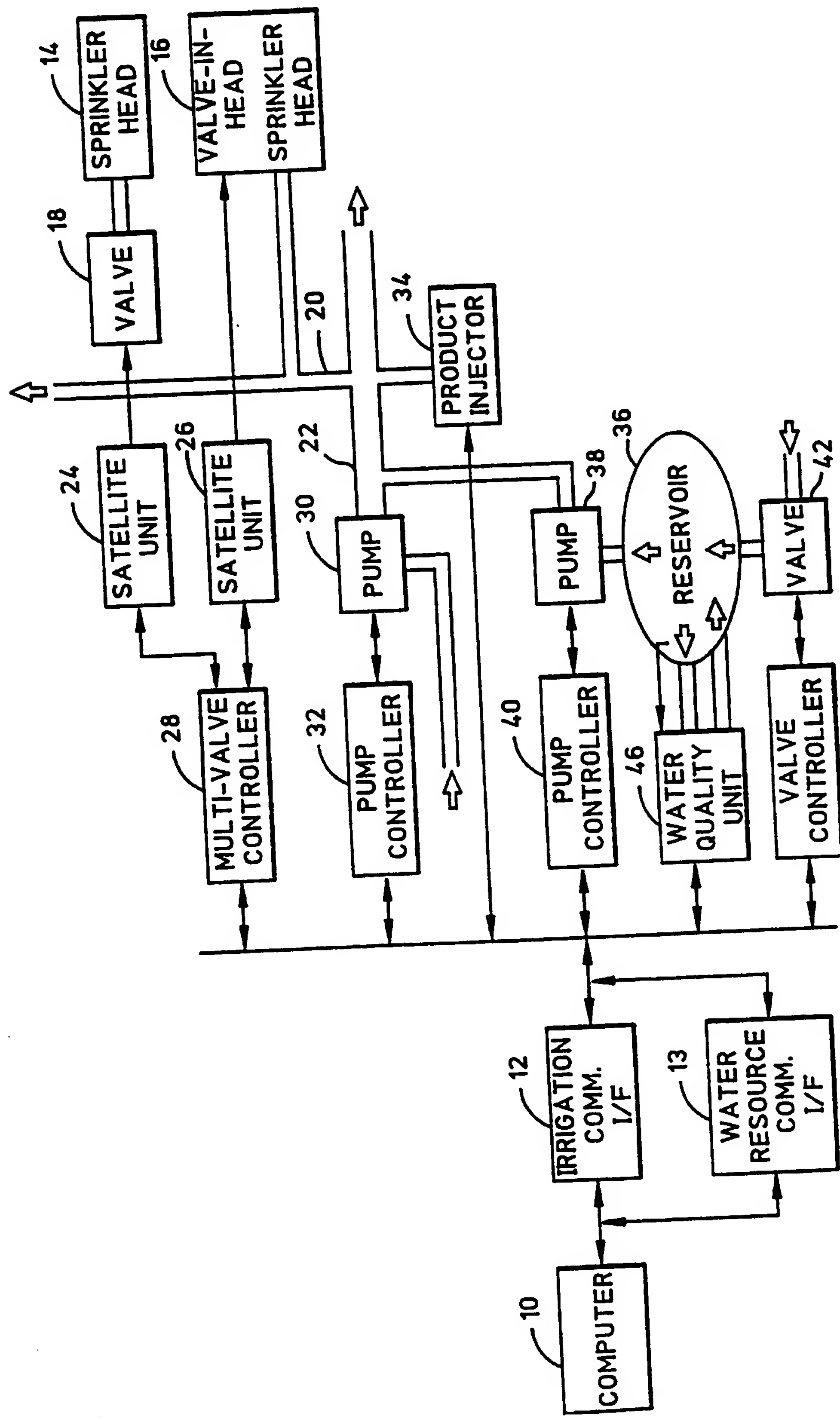

SPRINKLER HEAD
14
VALVE-IN-HEAD SPRINKLER HEAD
16
VALVE
18
20
34
PRODUCT INJECTOR
SATELLITE UNIT
24
SATELLITE UNIT
26
22
PUMP
30
PUMP
38
36
RESERVOIR
VALVE
42
MULTI-VALVE CONTROLLER
28
PUMP CONTROLLER
32
PUMP CONTROLLER
40
WATER QUALITY UNIT
46
VALVE CONTROLLER
44
IRRIGATION COMM. I/F
12
WATER RESOURCE COMM. I/F
13
COMPUTER
10

FIG. 1

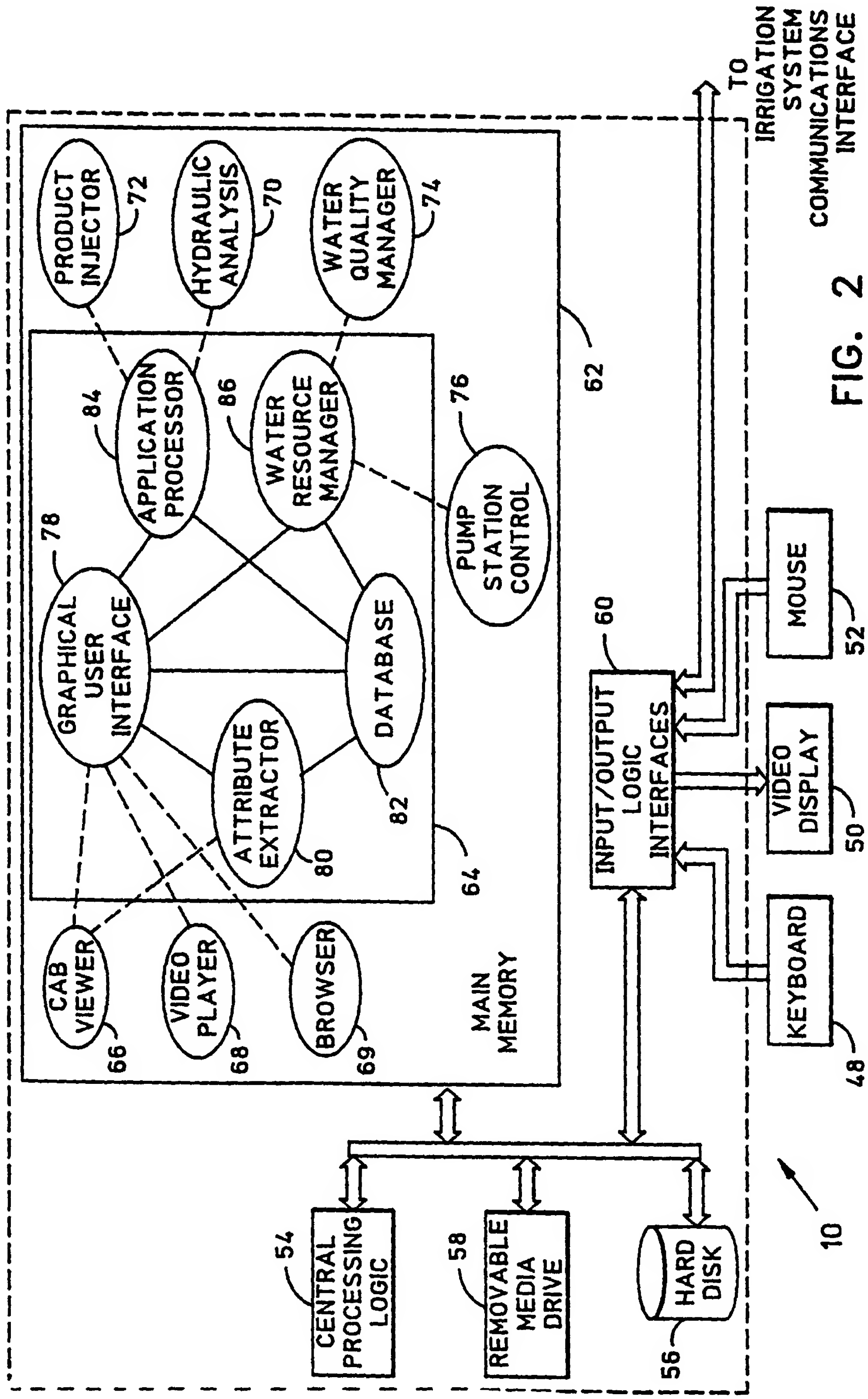

TO IRRIGATION SYSTEM COMMUNICATIONS INTERFACE
PRODUCT INJECTOR
72
HYDRAULIC ANALYSIS
70
WATER QUALITY MANAGER
74
APPLICATION PROCESSOR
84
WATER RESOURCE MANAGER
86
PUMP STATION CONTROL
76
62
GRAPHICAL USER INTERFACE
78
DATABASE
ATTRIBUTE EXTRACTOR
80
82
64
CAB VIEWER
66
VIDEO PLAYER
68
BROWSER
69
MAIN MEMORY
INPUT/OUTPUT LOGIC INTERFACES
60
MOUSE
52
VIDEO DISPLAY
50
KEYBOARD
48
CENTRAL PROCESSING LOGIC
54
REMOVABLE MEDIA DRIVE
58
HARD DISK
56
10

FIG. 2

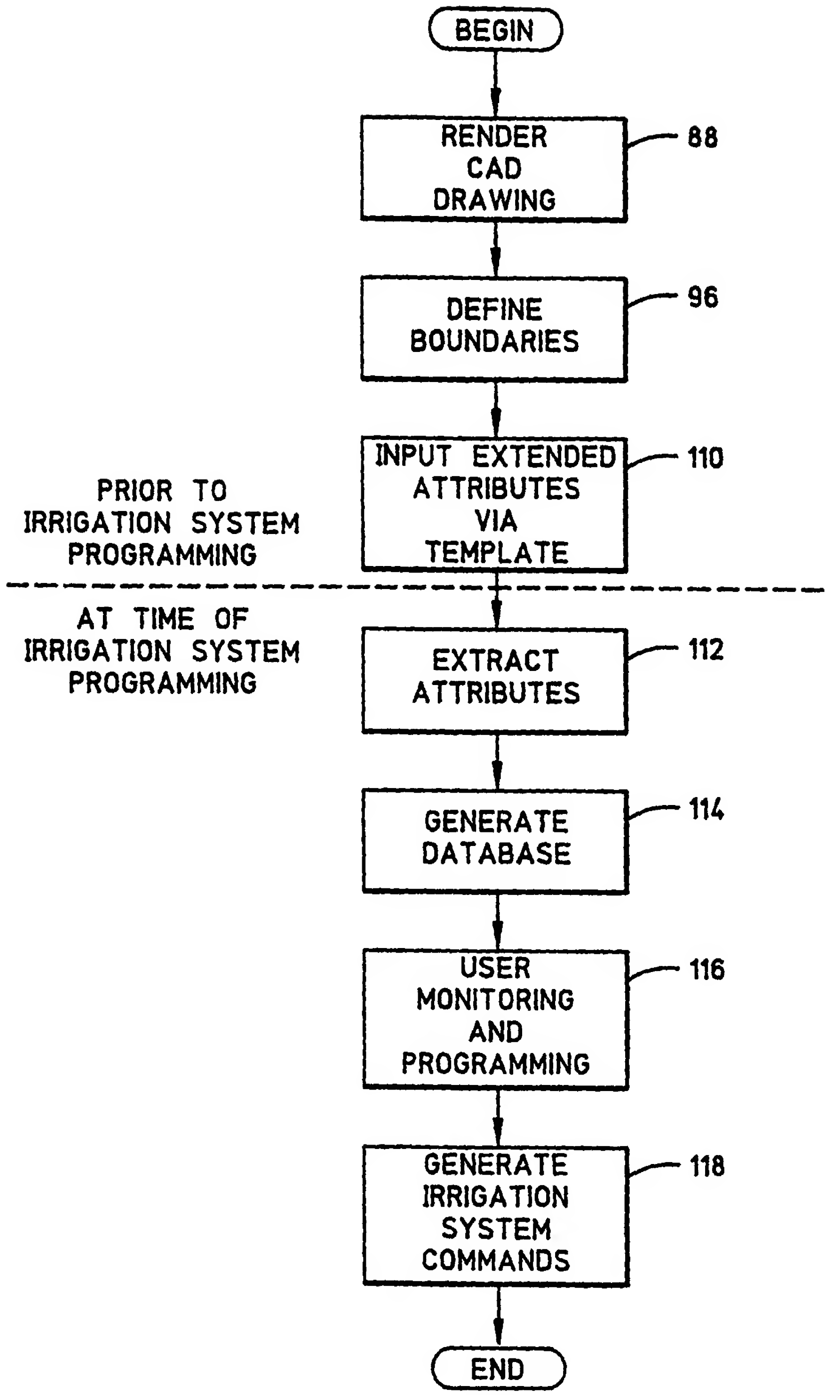

BEGIN
RENDER CAD DRAWING
88
DEFINE BOUNDARIES
96
INPUT EXTENDED ATTRIBUTES VIA TEMPLATE
110
PRIOR TO IRRIGATION SYSTEM PROGRAMMING
AT TIME OF IRRIGATION SYSTEM PROGRAMMING
EXTRACT ATTRIBUTES
112
GENERATE DATABASE
114
USER MONITORING AND PROGRAMMING
116
GENERATE IRRIGATION SYSTEM COMMANDS
118
END

FIG. 3

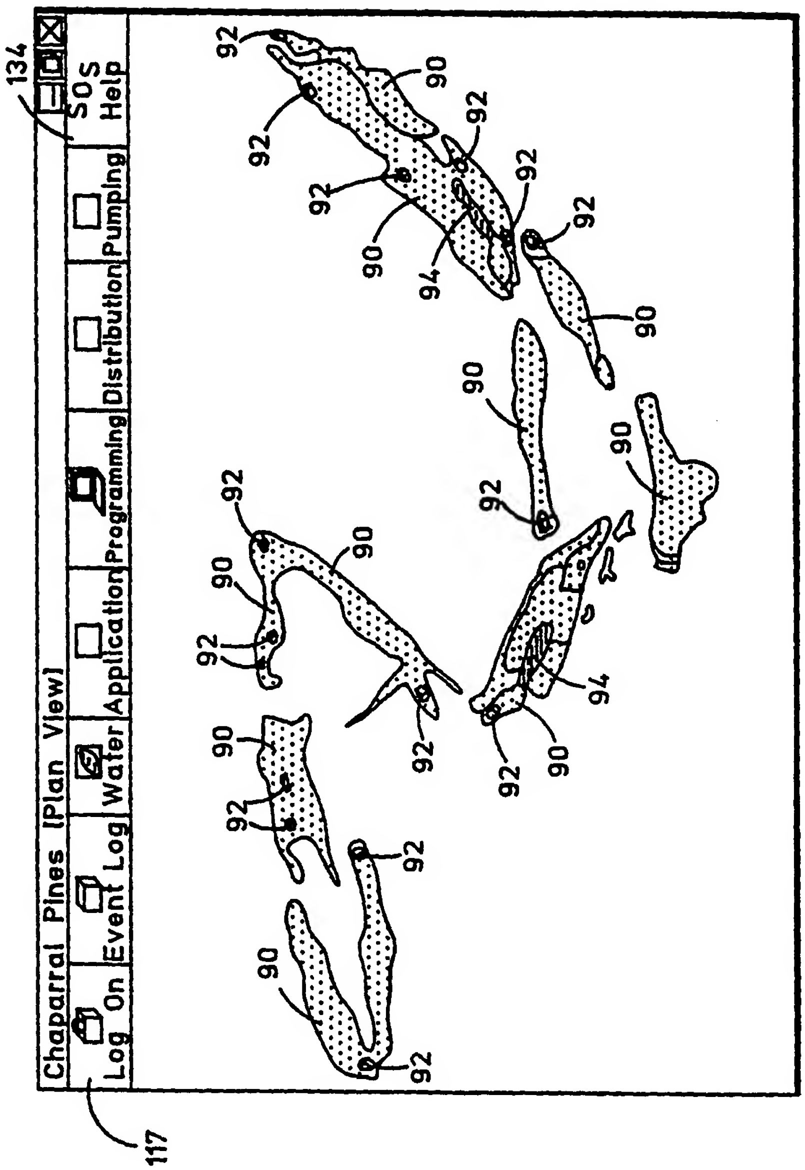

Chaparral Pines (Plan View)
Log On
Event Log
Water
Application
Programming
Distribution
Pumping
SOS Help
134
117
90
92
94

FIG. 4

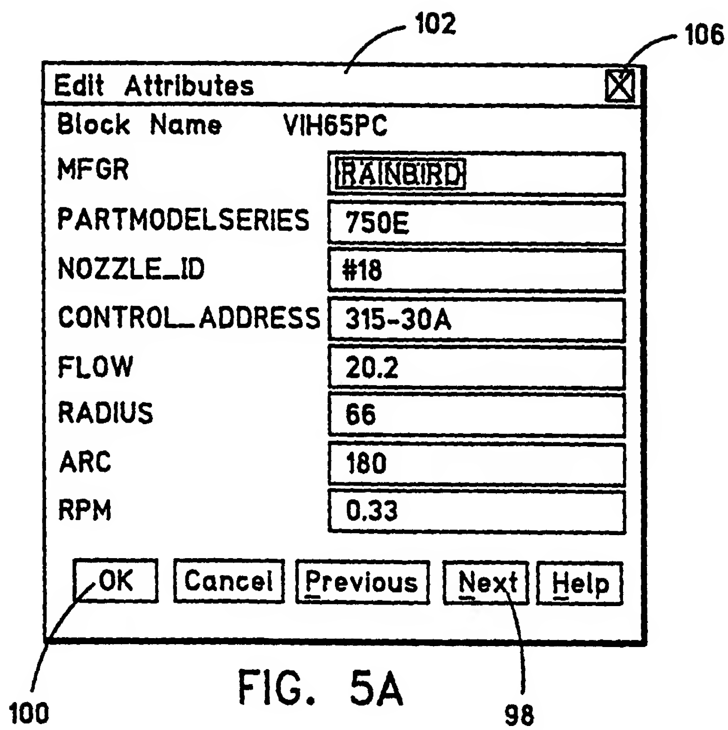

102
106
Edit Attributes
Block Name VIH65PC
MFGR
RAINBIRD
PARTMODELSERIES
750E
NOZZLE_ID
#18
CONTROL_ADDRESS
315-30A
FLOW
20.2
RADIUS
66
ARC
180
RPM
0.33
OK
Cancel
Previous
Next
Help
100
98

FIG. 5A

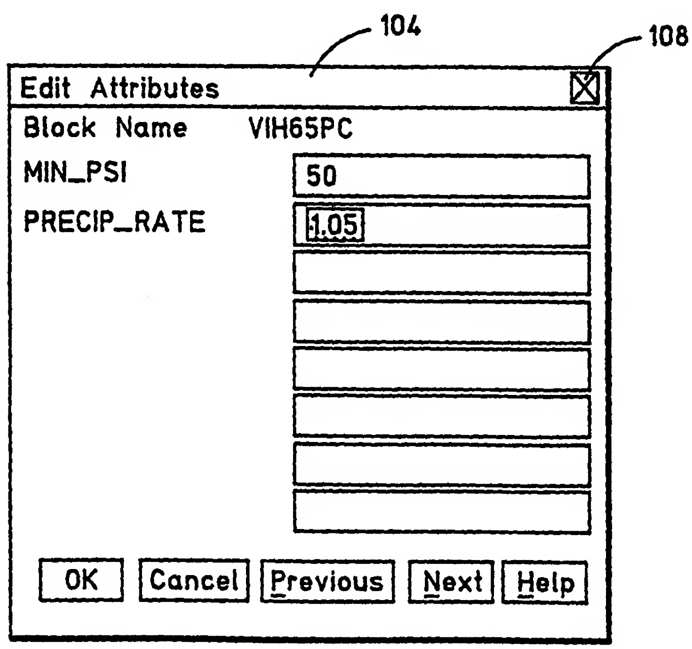

104
108
Edit Attributes
Block Name VIH65PC
MIN_PSI
50
PRECIP_RATE
1.05
OK
Cancel
Previous
Next
Help

FIG. 5B

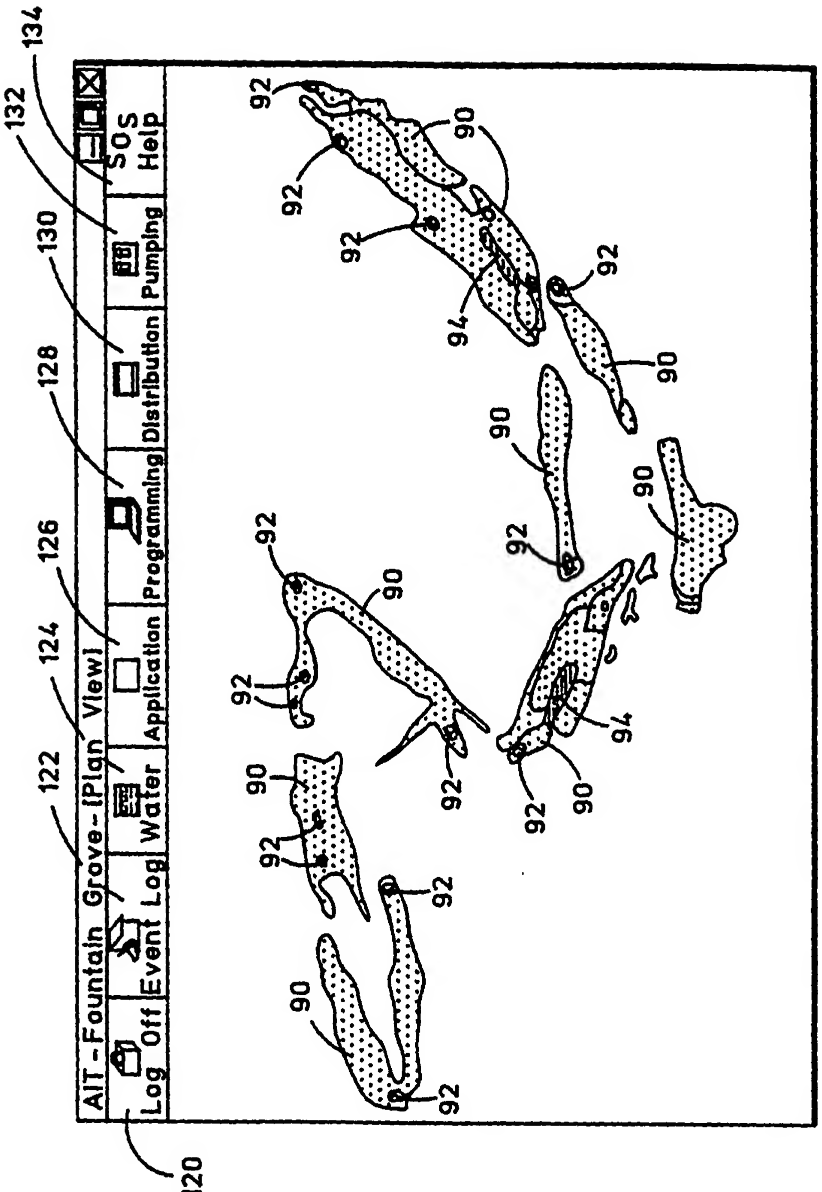

AIT-Fountain Grove-IPlan View1
Log Off
Event Log
Water
Application
Programming
Distribution
Pumping
SOS Help
120
122
124
126
128
130
132
134
90
92
94

FIG. 6

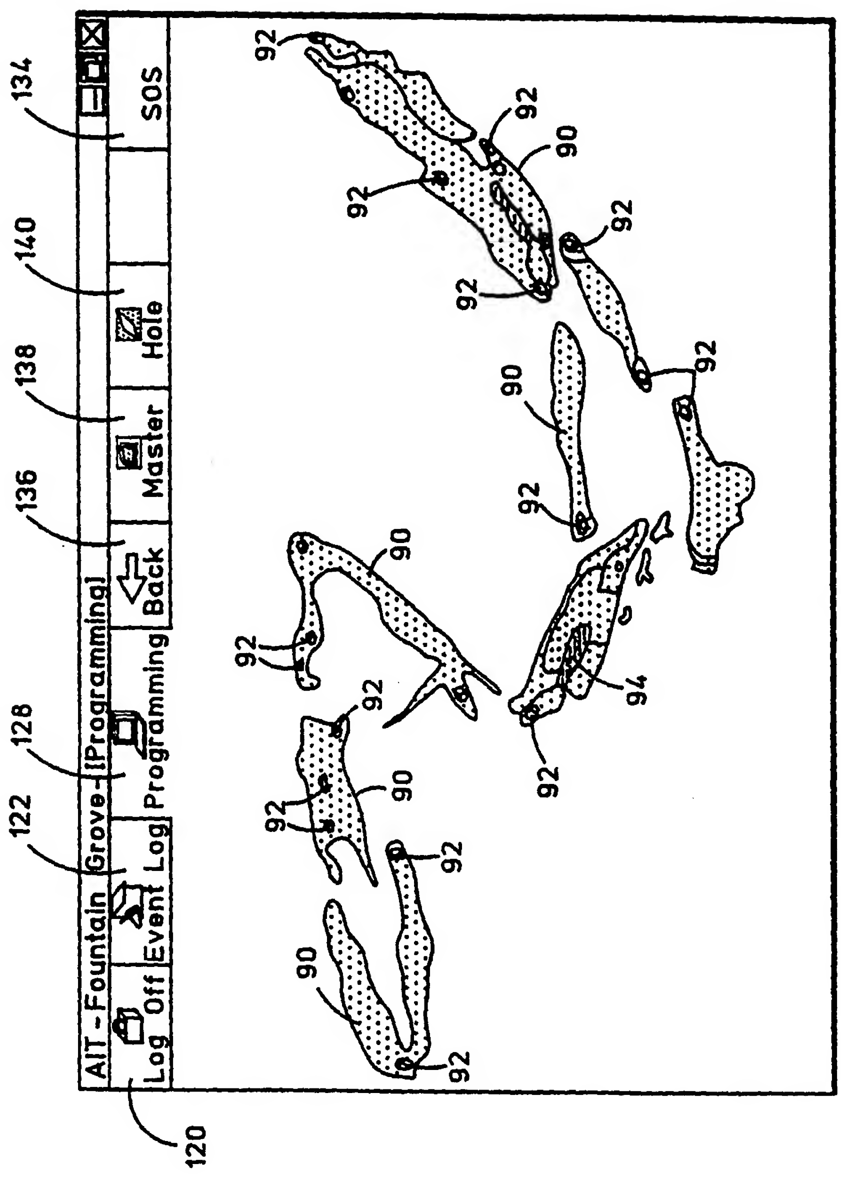

AIT - Fountain Grove - [Programming]
Log Off
Event Log
Programming
Back
Master
Hole
SOS
120
122
128
134
136
138
140
90
92
94

FIG. 7

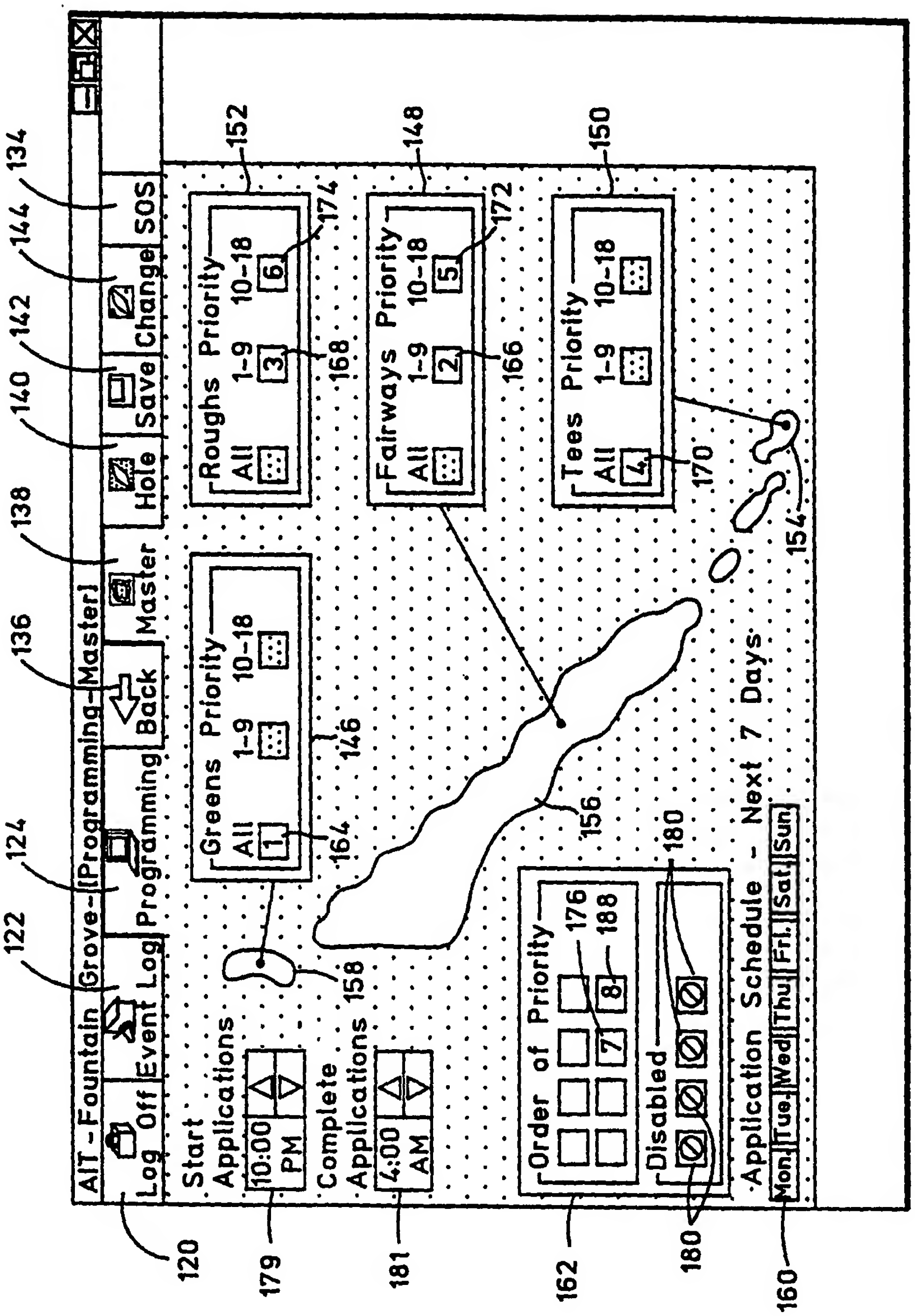

AIT - Fountain Grove - [Programming - Master]
Log Off
Event Log
Programming
Back
Master
Hole
Save
Change
SOS
Start Applications
10:00 PM
Complete Applications
4:00 AM
Greens Priority
All 1-9 10-18
1
Roughs Priority
All 1-9 10-18
3
6
Fairways Priority
All 1-9 10-18
2
5
Tees Priority
All 1-9 10-18
4
Order of Priority
7
8
Disabled
Application Schedule - Next 7 Days
Mon. Tue. Wed. Thu. Fri. Sat. Sun.
120
122
124
134
136
138
140
142
144
146
148
150
152
154
156
158
160
162
164
166
168
170
172
174
176
179
180
181
188

FIG. 8

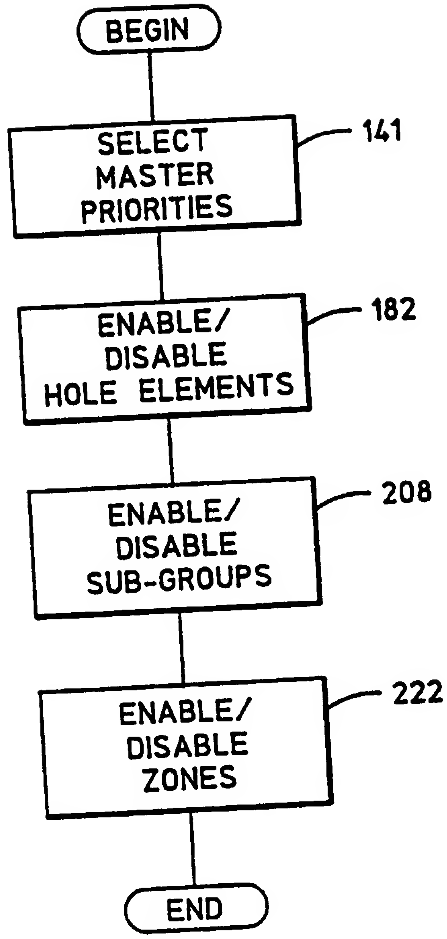

BEGIN
SELECT MASTER PRIORITIES
141
ENABLE/ DISABLE HOLE ELEMENTS
182
ENABLE/ DISABLE SUB-GROUPS
208
ENABLE/ DISABLE ZONES
222
END

FIG. 9

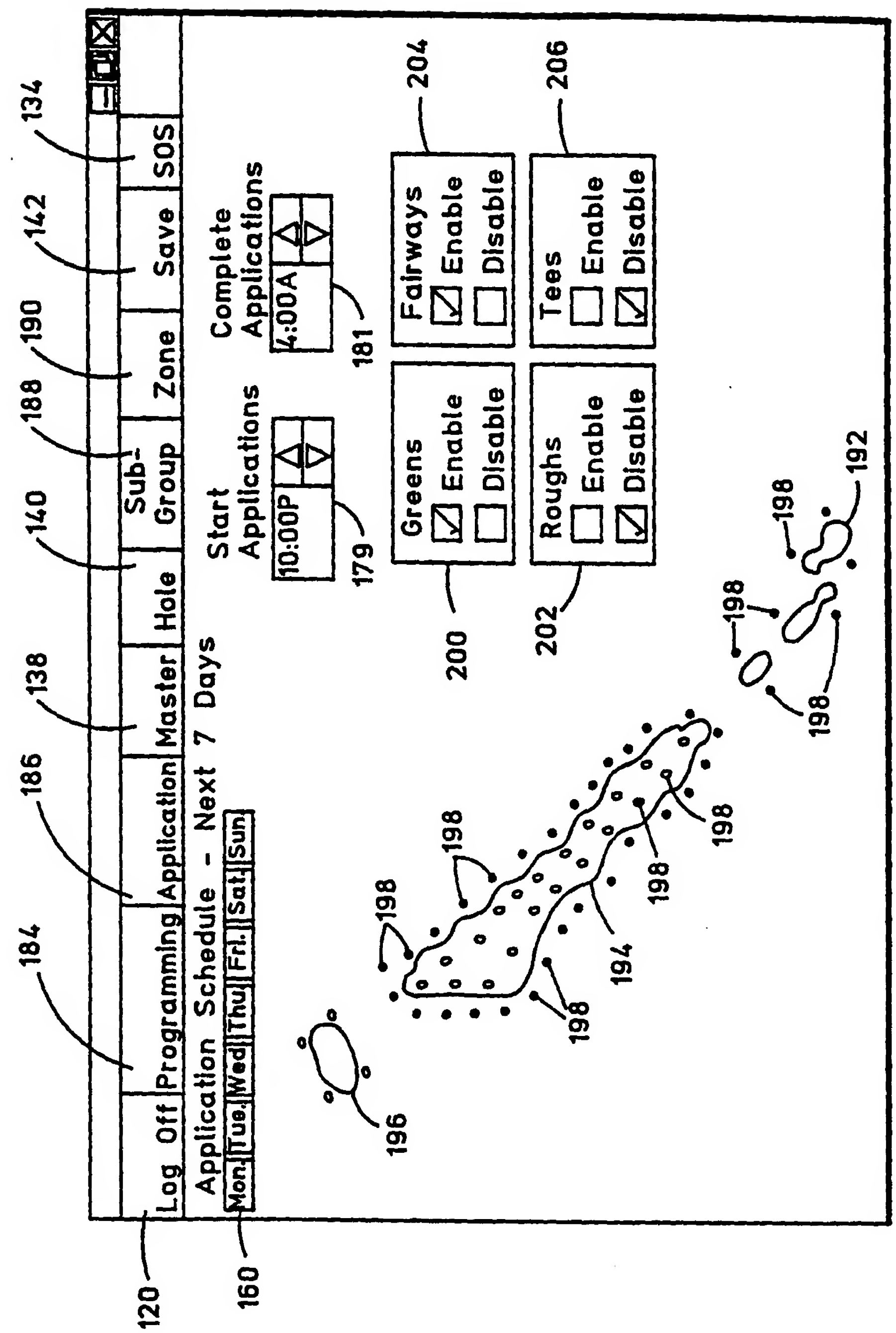

Log Off
Programming
Application
Master
Hole
Sub-Group
Zone
Save
SOS
Application Schedule - Next 7 Days
Mon. Tue. Wed. Thu. Fri. Sat. Sun
Start Applications
10:00P
Complete Applications
4:00A
Greens
Enable
Disable
Fairways
Enable
Disable
Roughs
Enable
Disable
Tees
Enable
Disable
120
160
184
186
138
140
188
190
142
134
179
181
200
202
204
206
192
194
196
198

FIG. 10

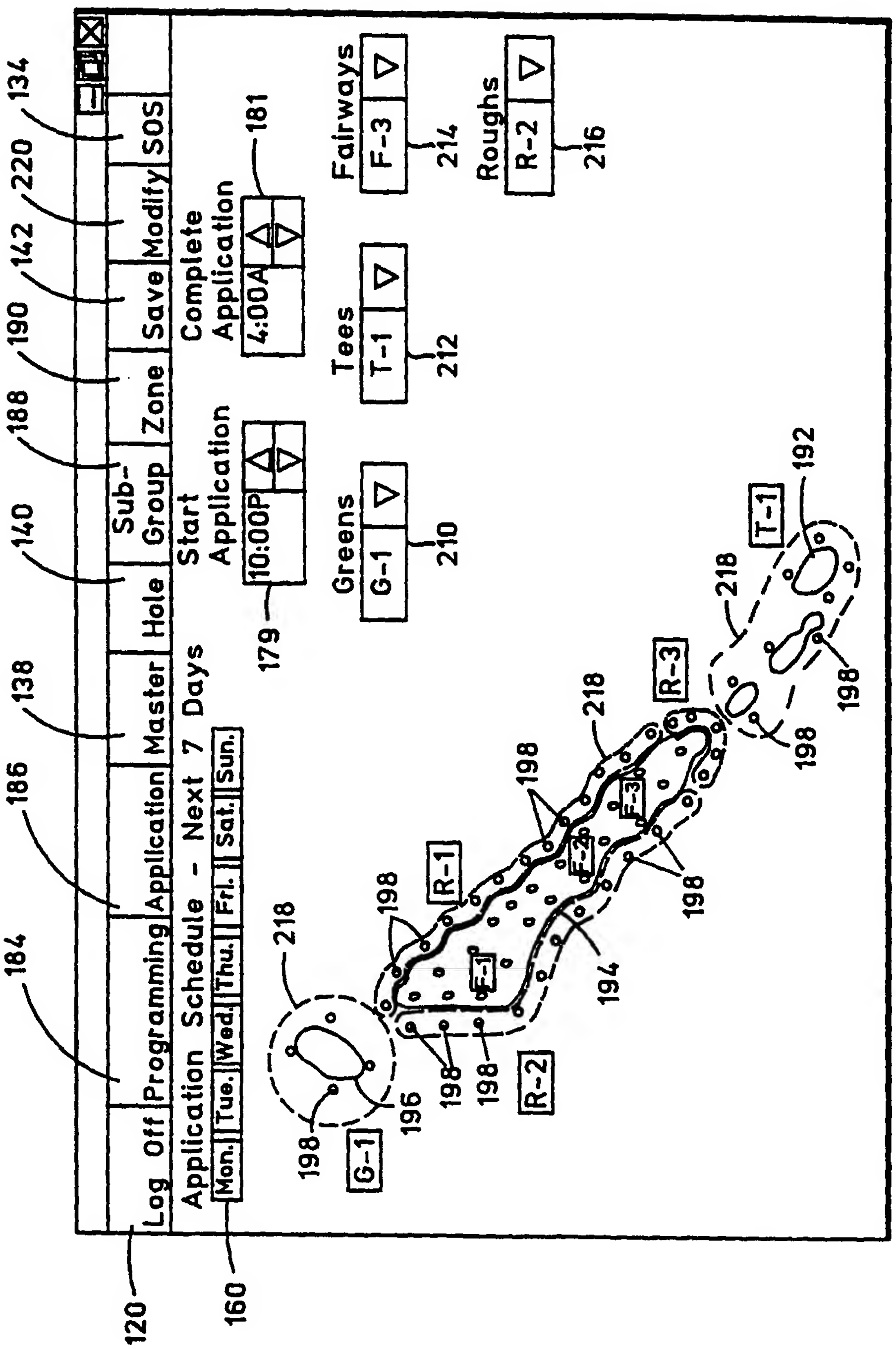

Log Off
Programming
Application
Master
Hole
Sub-Group
Zone
Save
Modify
SOS
Application Schedule - Next 7 Days
Mon.
Tue.
Wed.
Thu.
Fri.
Sat.
Sun.
Start Application
10:00P
Complete Application
4:00A
Greens
G-1
Tees
T-1
Fairways
F-3
Roughs
R-2
G-1
R-1
R-2
R-3
T-1
F-1
F-2
F-3
120
160
184
186
138
140
188
190
142
220
134
179
181
210
212
214
216
218
196
198
194
192

FIG. 11

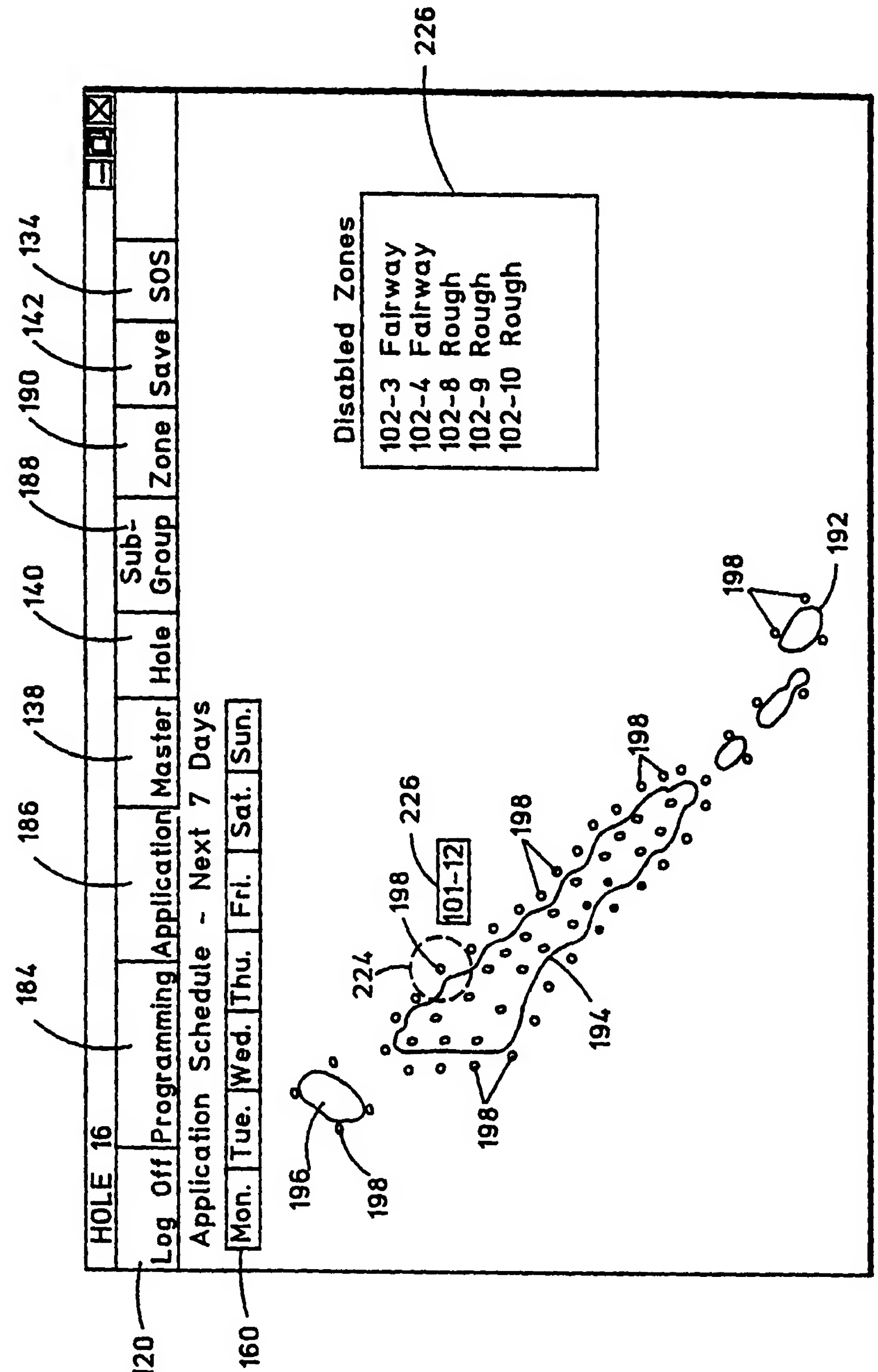

HOLE 16
Log Off
Programming
Application
Master
Hole
Sub-Group
Zone
Save
SOS
Application Schedule - Next 7 Days
Mon.
Tue.
Wed.
Thu.
Fri.
Sat.
Sun.
Disabled Zones
102-3 Fairway
102-4 Fairway
102-8 Rough
102-9 Rough
102-10 Rough
101-12
120
160
184
186
138
140
188
190
142
134
226
224
198
196
194
192

FIG. 12

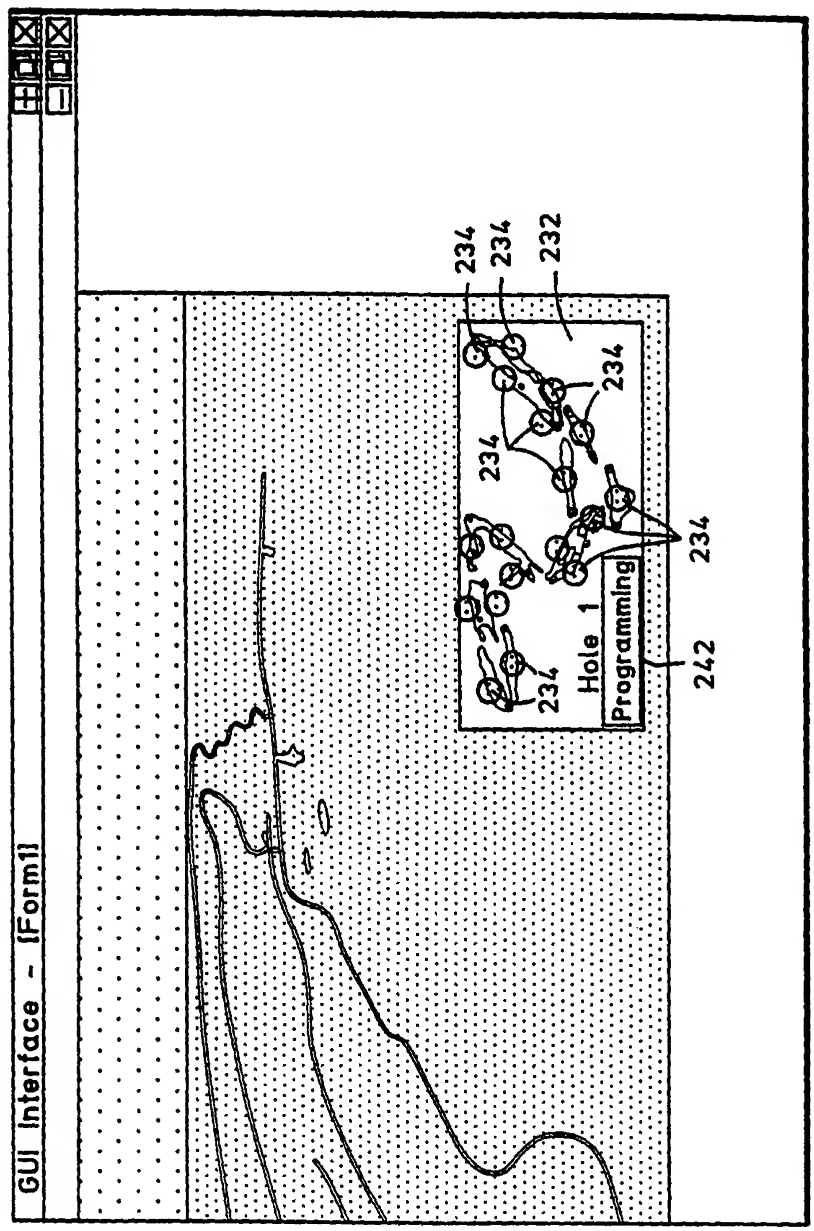


FIG. 13

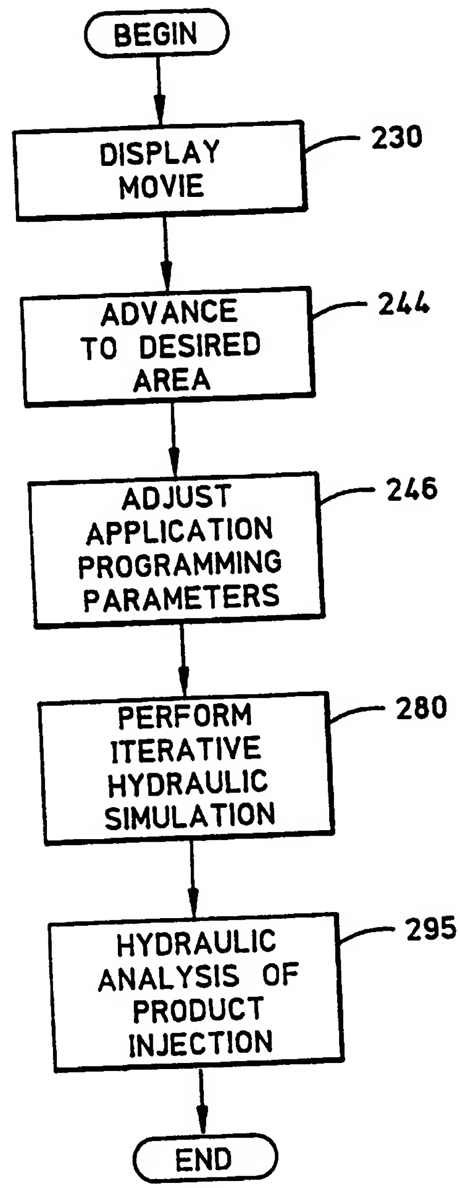

BEGIN
DISPLAY MOVIE
230
ADVANCE TO DESIRED AREA
244
ADJUST APPLICATION PROGRAMMING PARAMETERS
246
PERFORM ITERATIVE HYDRAULIC SIMULATION
280
HYDRAULIC ANALYSIS OF PRODUCT INJECTION
295
END

FIG. 14

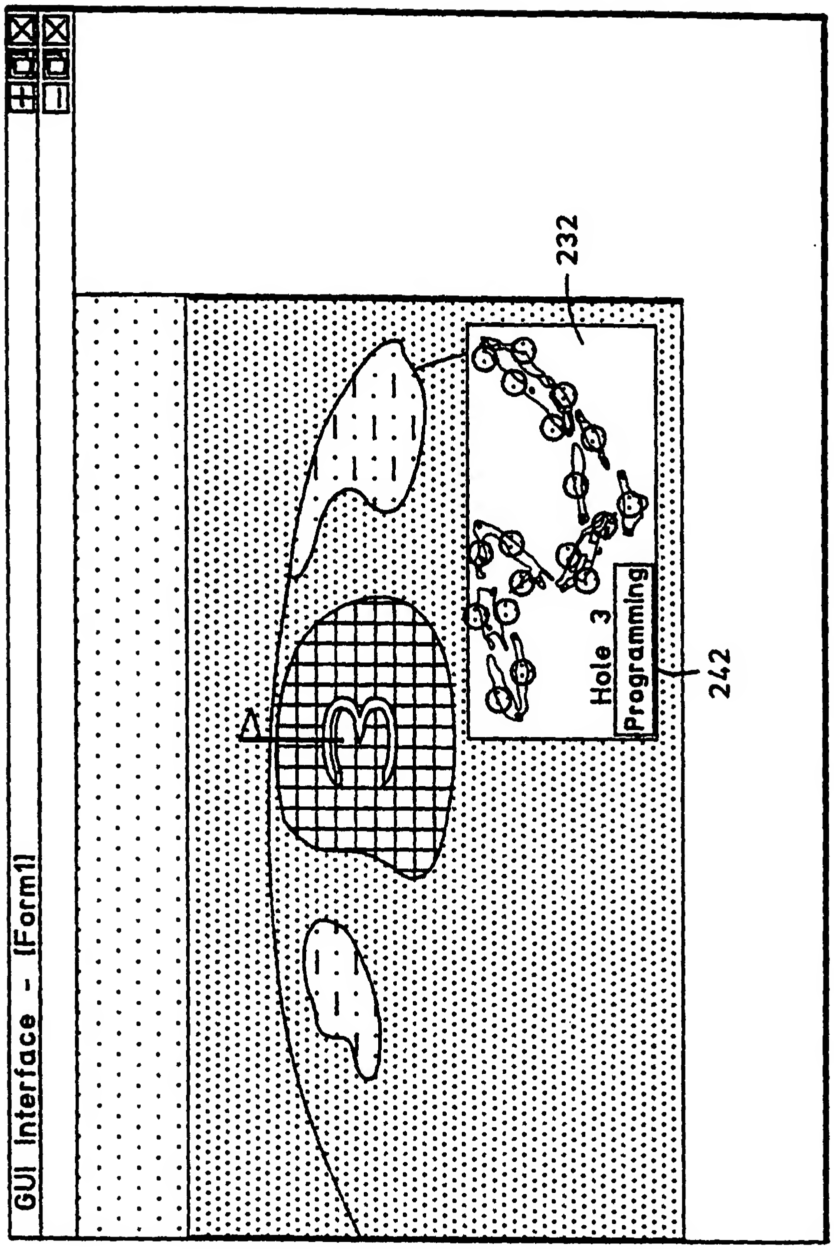


FIG. 15

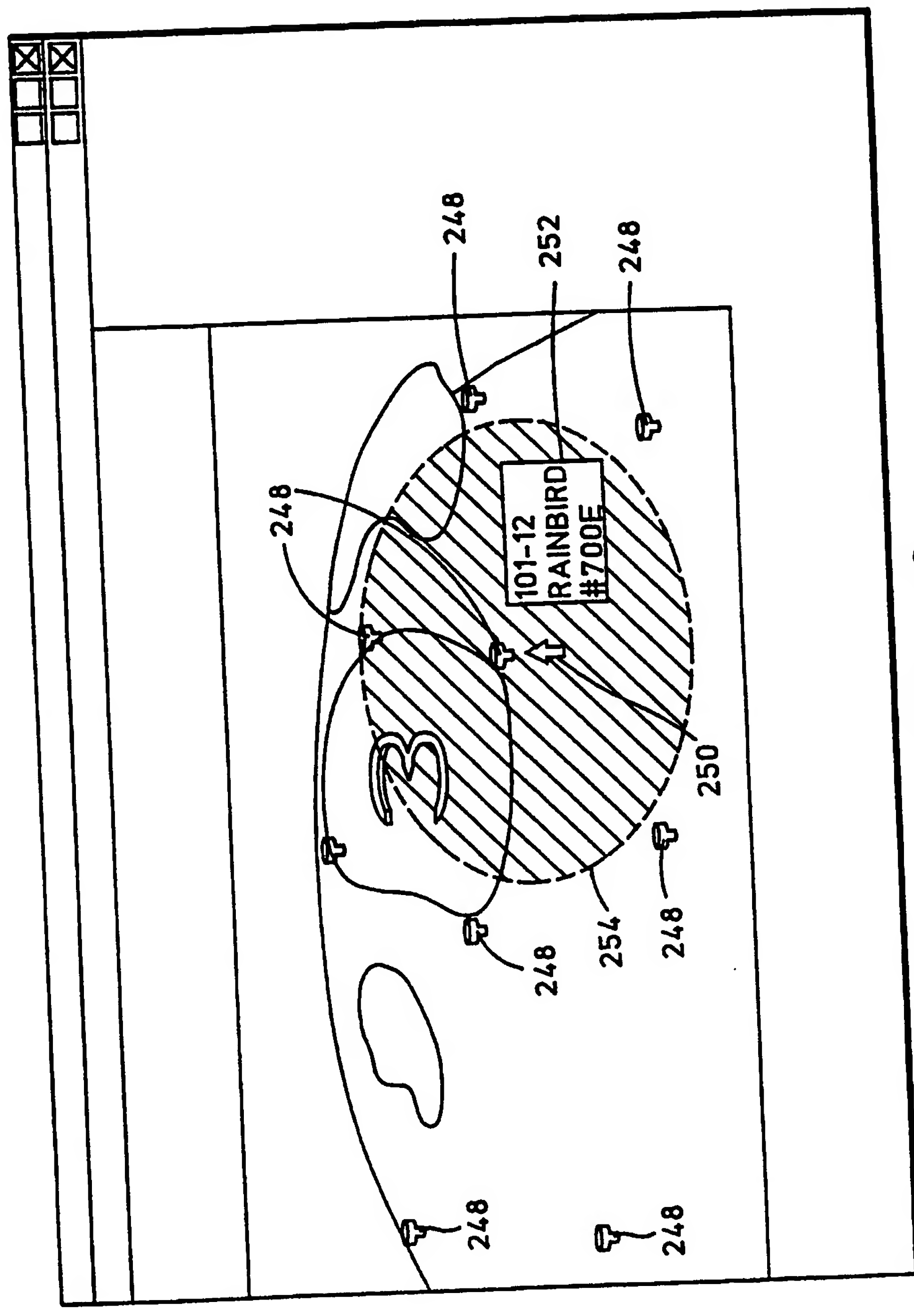


FIG. 16

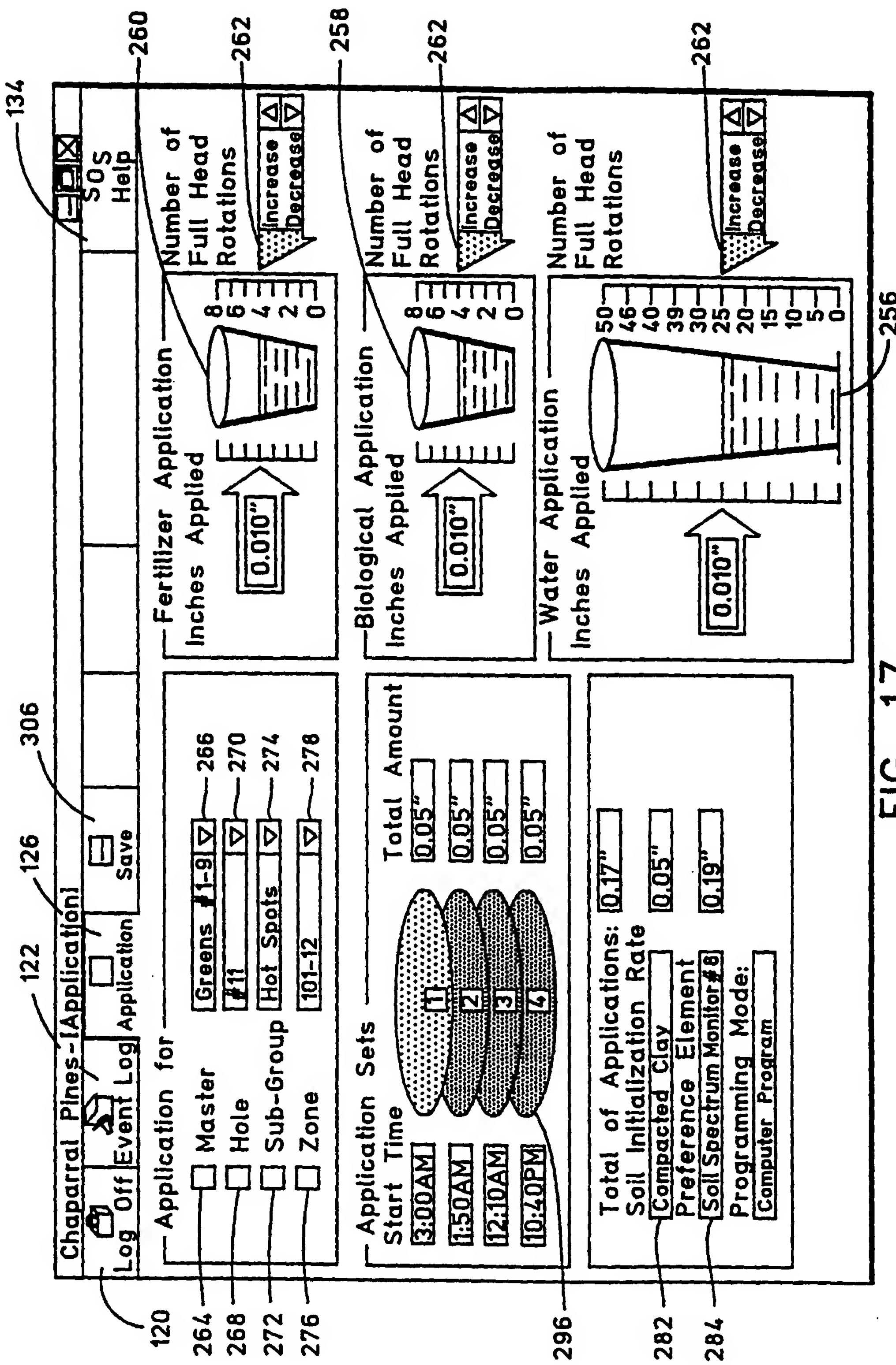

Chaparral Pines-[Application]
Log Off
Event Log
Application
Save
SOS Help
Application for
Master
Hole
Sub-Group
Zone
Greens #1-9
#11
Hot Spots
101-12
Application Sets
Start Time
Total Amount
3:00AM
1:50AM
12:10AM
10:40PM
1
2
3
4
0.05"
0.05"
0.05"
0.05"
Total of Applications:
0.17"
Soil Initialization Rate
Compacted Clay
0.05"
Preference Element
Soil Spectrum Monitor #8
0.19"
Programming Mode:
Computer Program
Fertilizer Application
Biological Application
Water Application
Inches Applied
0.010"
Number of Full Head Rotations
Increase
Decrease
8
6
4
2
0
50
46
40
39
30
25
20
15
10
5
0
120
122
126
134
306
260
262
258
256
264
268
272
276
296
282
284

FIG. 17

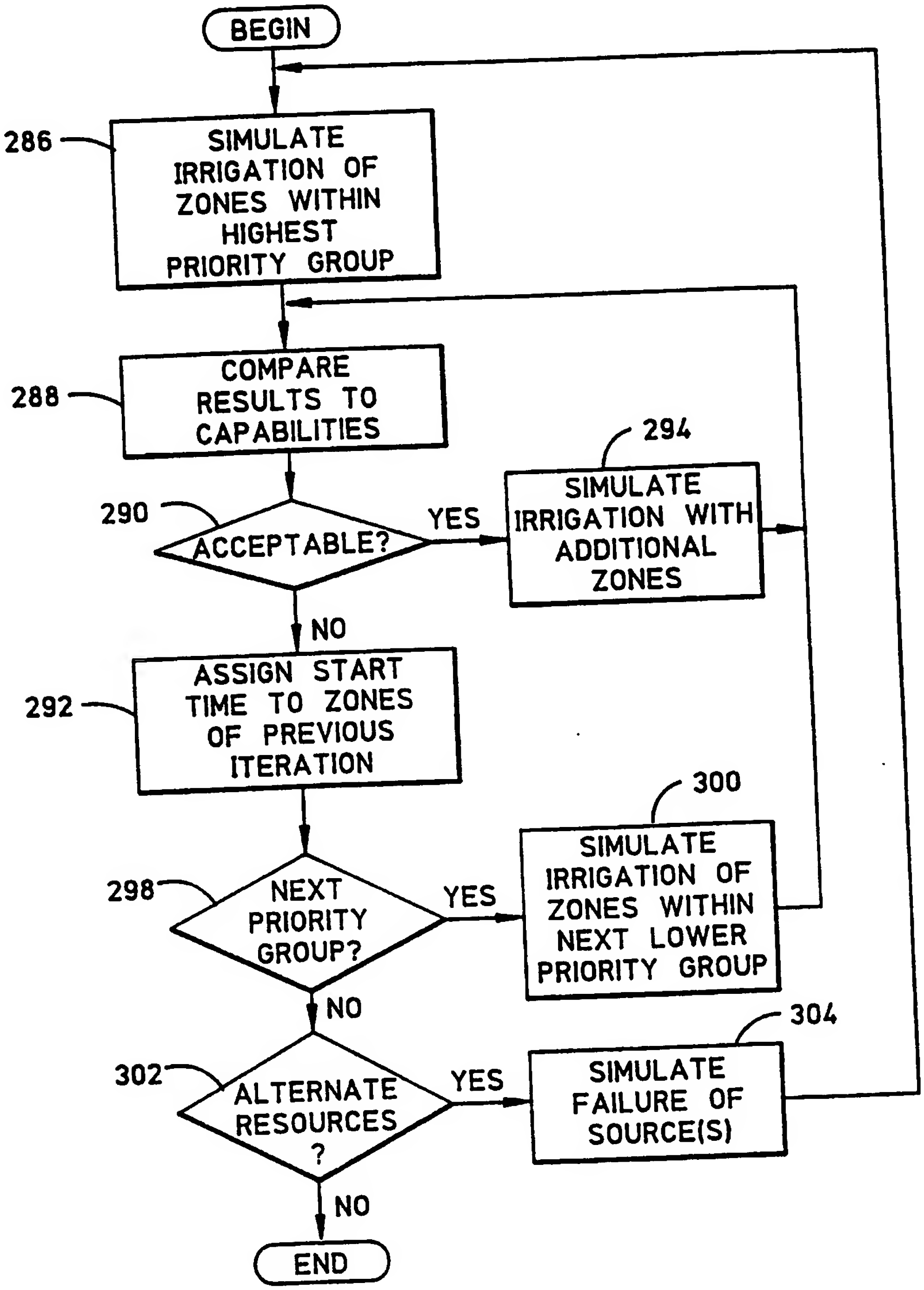

BEGIN
286
SIMULATE IRRIGATION OF ZONES WITHIN HIGHEST PRIORITY GROUP
288
COMPARE RESULTS TO CAPABILITIES
290
ACCEPTABLE?
YES
294
SIMULATE IRRIGATION WITH ADDITIONAL ZONES
NO
292
ASSIGN START TIME TO ZONES OF PREVIOUS ITERATION
298
NEXT PRIORITY GROUP?
YES
300
SIMULATE IRRIGATION OF ZONES WITHIN NEXT LOWER PRIORITY GROUP
NO
302
ALTERNATE RESOURCES ?
YES
304
SIMULATE FAILURE OF SOURCE(S)
NO
END

FIG. 18

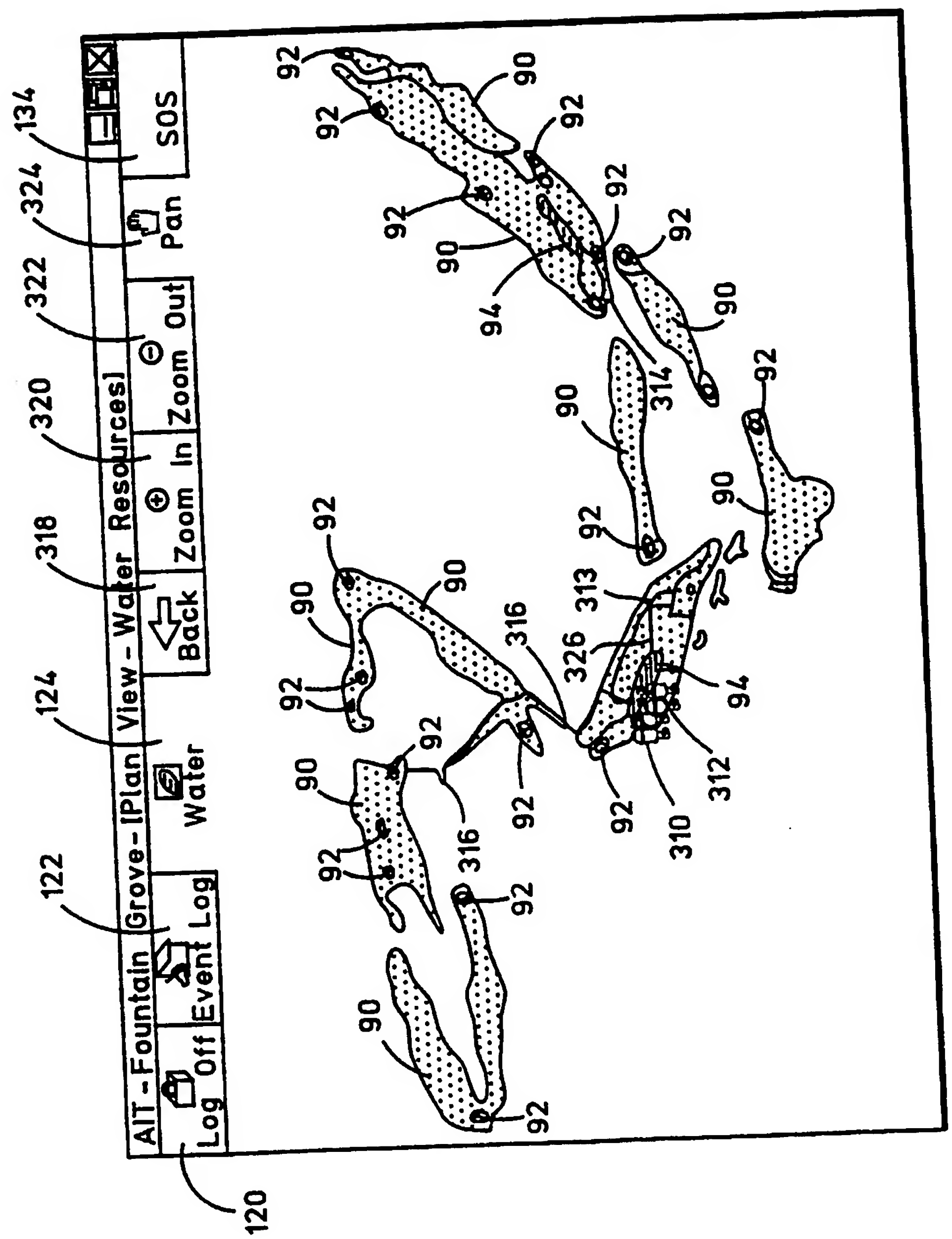

AIT - Fountain Grove - IPlan View - Water Resources)
Log Off
Event Log
Water
Back
Zoom In
Zoom Out
Pan
SOS
120
122
124
134
318
320
322
324
90
92
94
310
312
313
314
316
326

FIG. 19

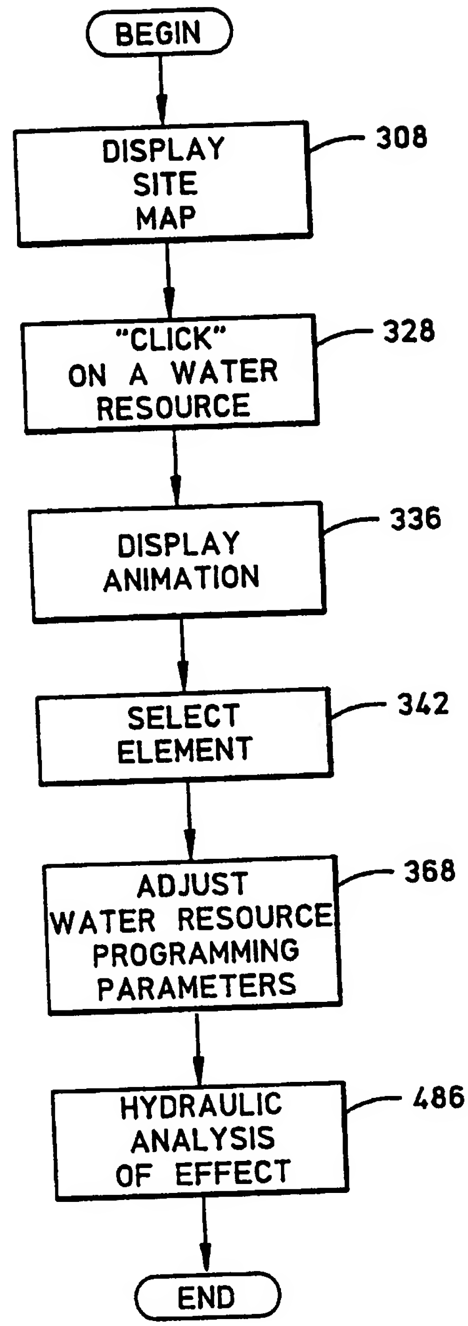

BEGIN
DISPLAY SITE MAP
308
"CLICK" ON A WATER RESOURCE
328
DISPLAY ANIMATION
336
SELECT ELEMENT
342
ADJUST WATER RESOURCE PROGRAMMING PARAMETERS
368
HYDRAULIC ANALYSIS OF EFFECT
486
END

FIG. 20

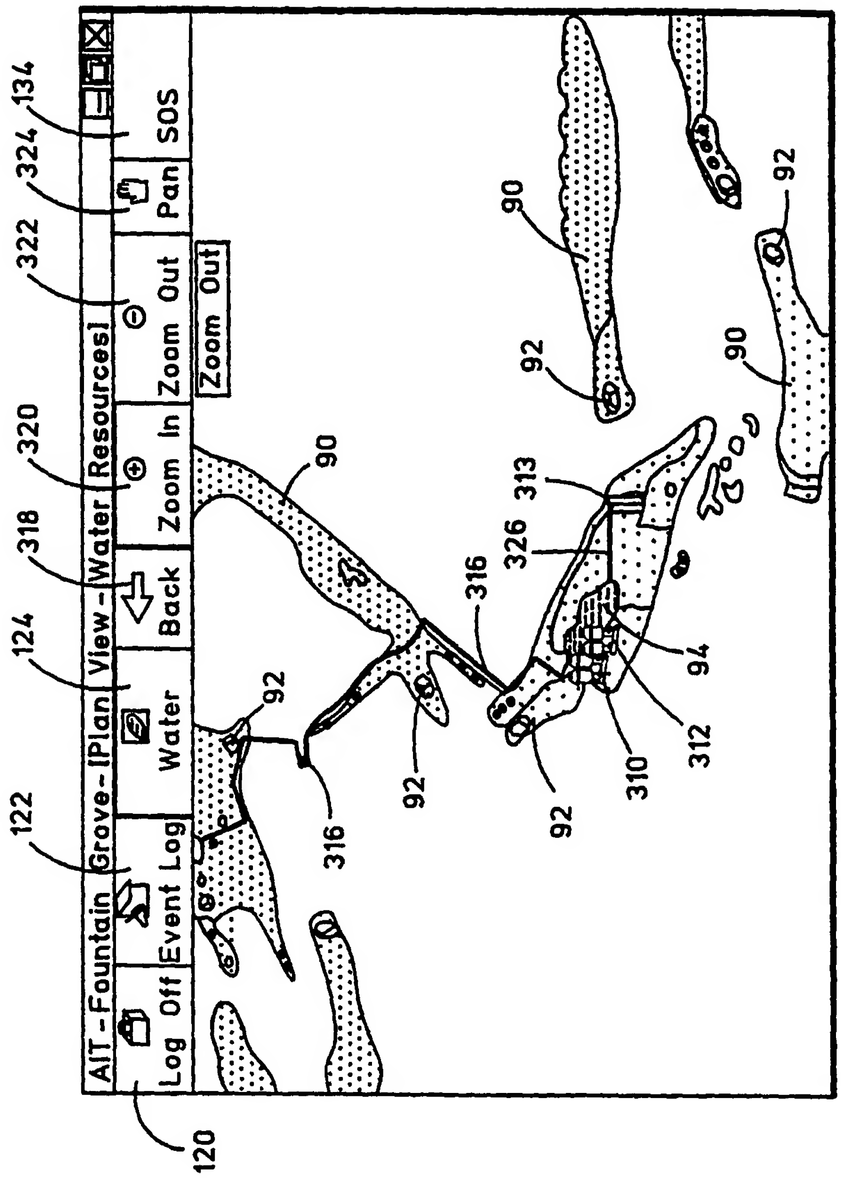

AIT-Fountain Grove-[Plan View-Water Resources]
Log Off
Event Log
Water
Back
Zoom In
Zoom Out
Pan
SOS
Zoom Out
120
122
124
318
320
322
324
134
90
92
94
310
312
313
316
326

FIG. 21

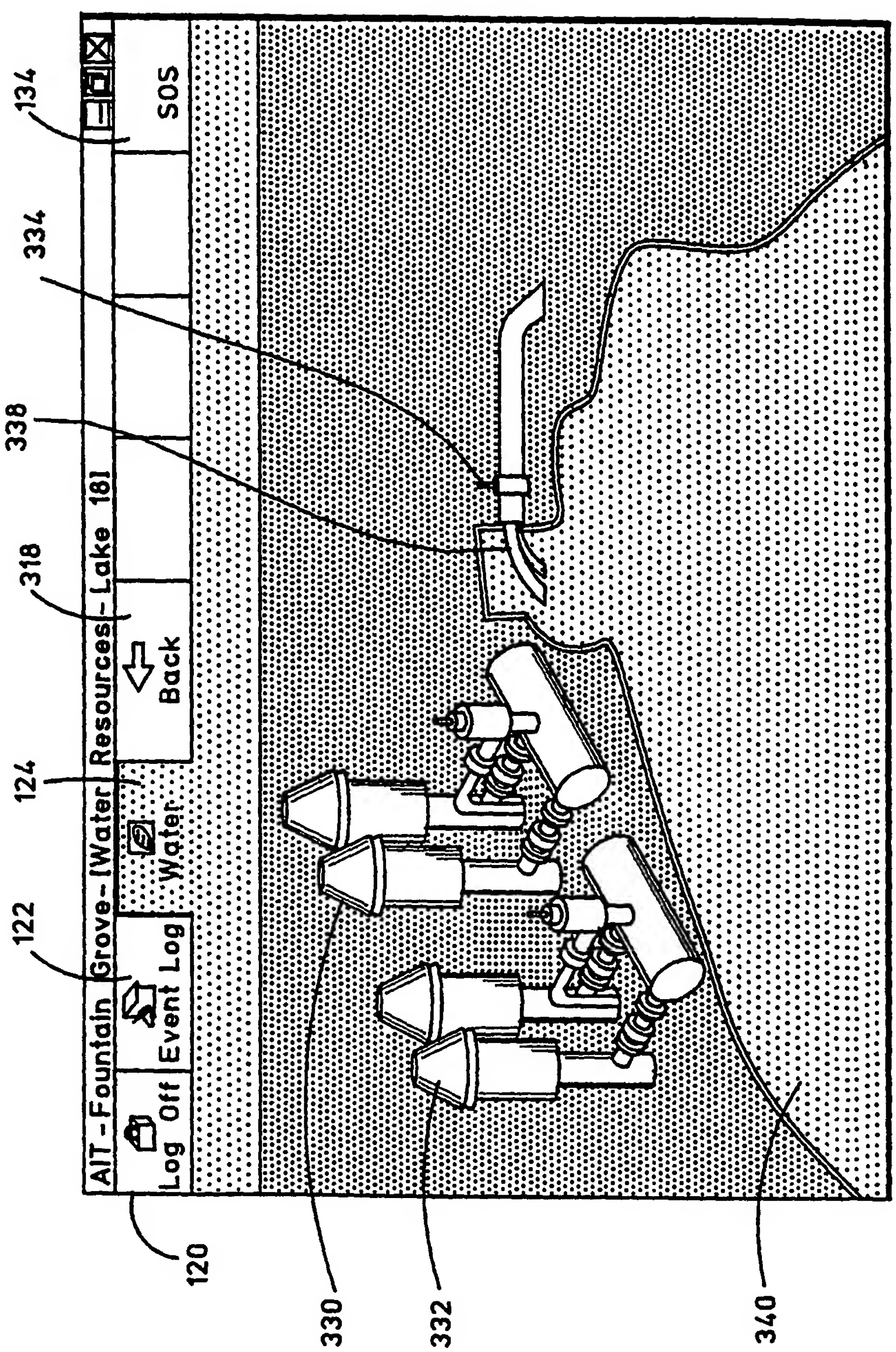

AIT-Fountain Grove-[Water Resources-Lake 18]
Log Off
Event Log
Water
Back
SOS
120
122
124
318
338
334
134
330
332
340

FIG. 22

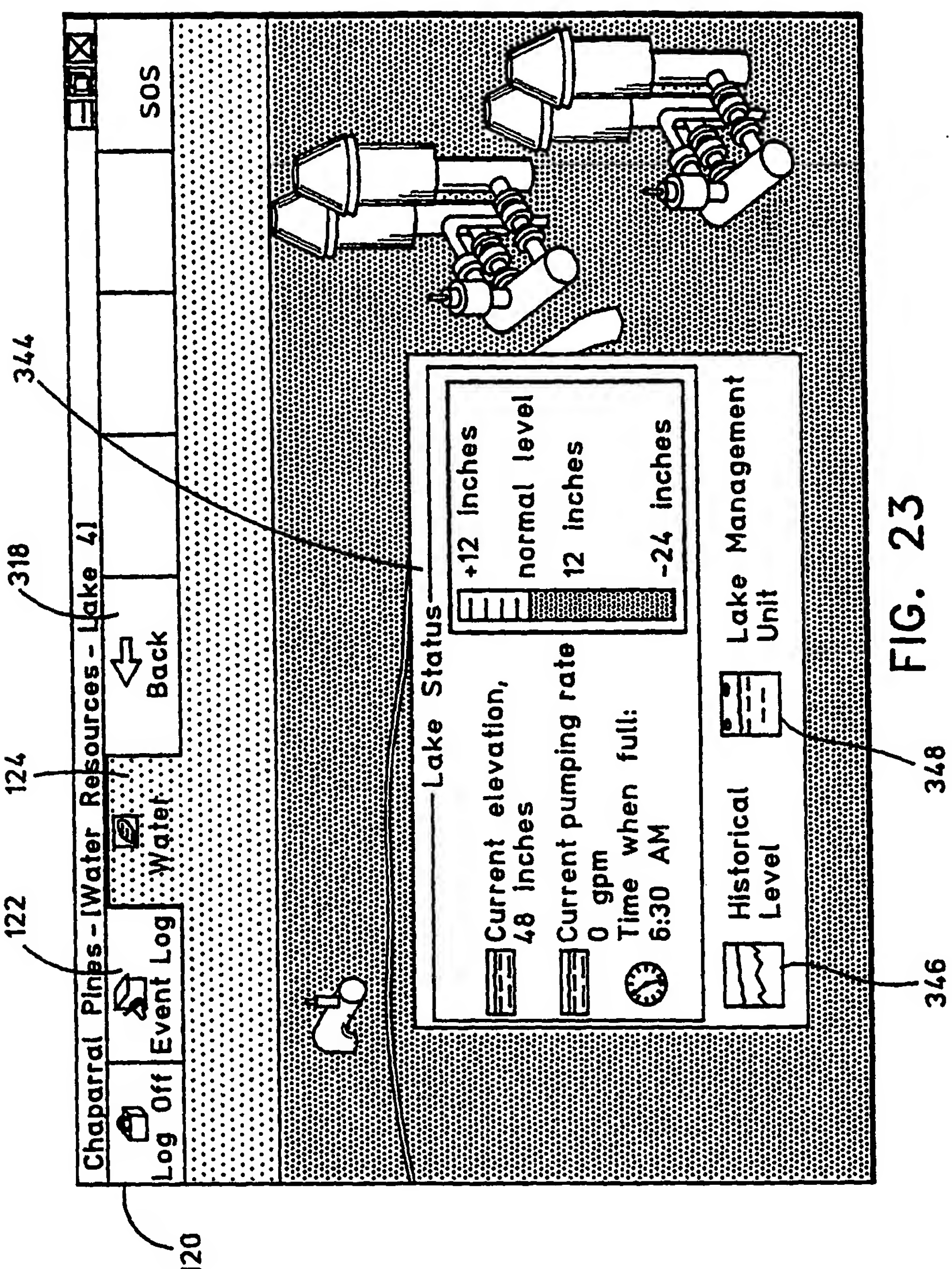

Chaparral Pines - [Water Resources - Lake 4]
Log Off
Event Log
Water
Back
SOS
Lake Status
Current elevation, 48 inches
Current pumping rate 0 gpm
Time when full: 6:30 AM
+12 Inches
normal level
12 Inches
-24 Inches
Historical Level
Lake Management Unit
120
122
124
318
344
346
348

FIG. 23

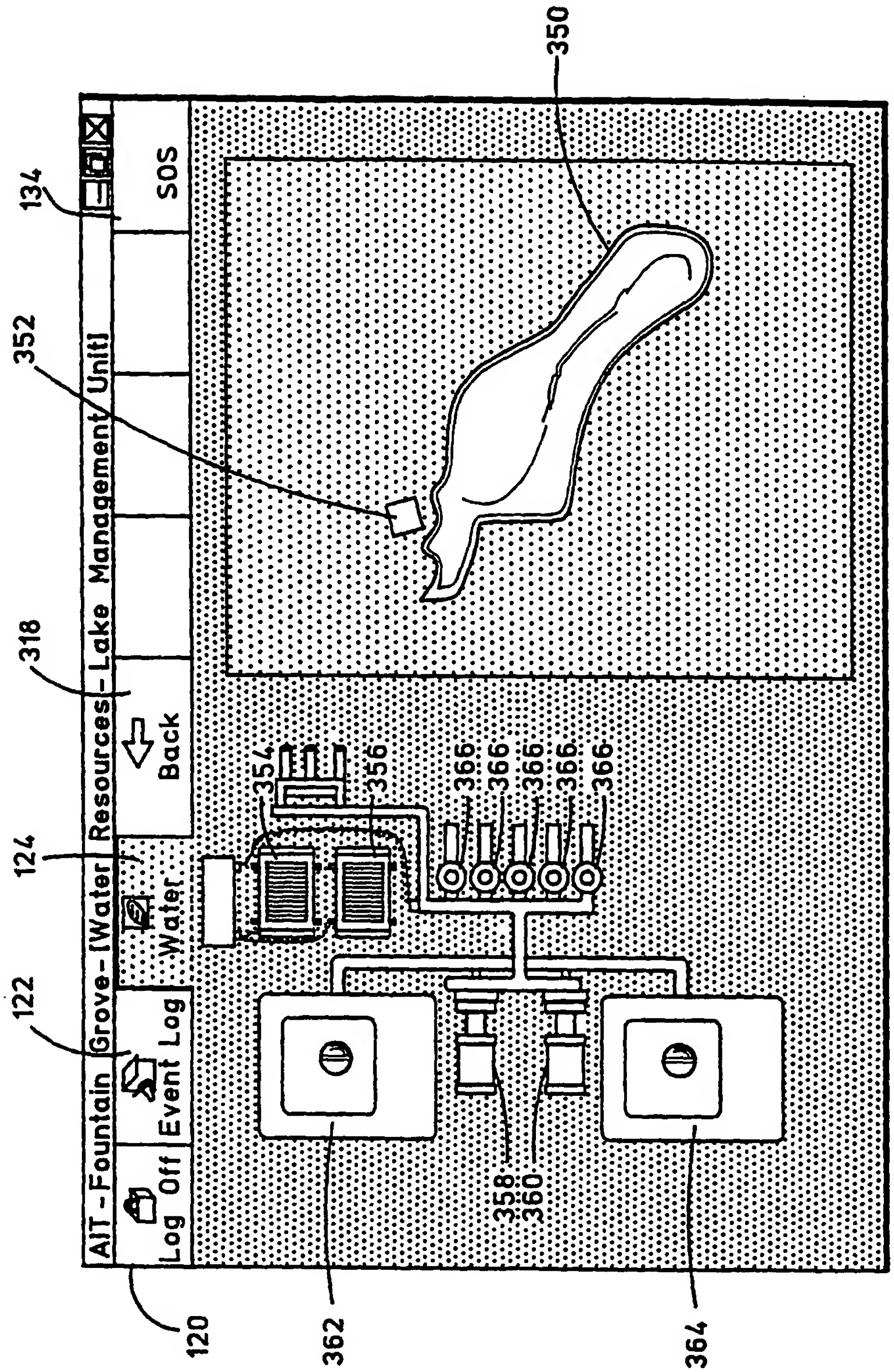

AIT - Fountain Grove - [Water Resources - Lake Management Unit]
Log Off
Event Log
Water
Back
SOS
120
122
124
318
352
134
350
354
356
366
366
366
366
366
358
360
362
364

FIG. 24

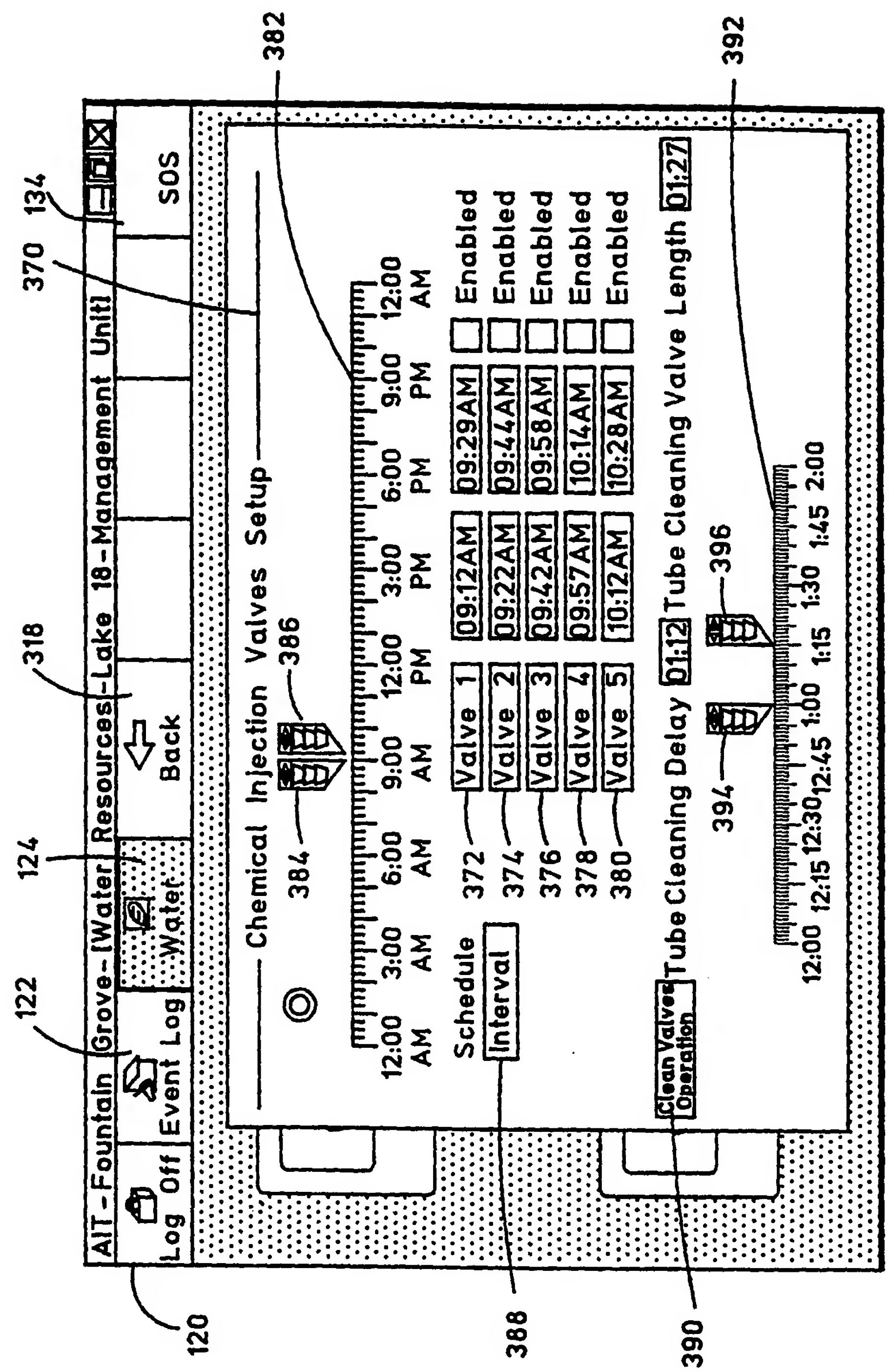

AIT-Fountain Grove-[Water Resources-Lake 18-Management Unit]
Log Off
Event Log
Water
Back
SOS
Chemical Injection Valves Setup
12:00 AM
3:00 AM
6:00 AM
9:00 AM
12:00 PM
3:00 PM
6:00 PM
9:00 PM
12:00 AM
Schedule
Interval
Valve 1
Valve 2
Valve 3
Valve 4
Valve 5
09:12AM
09:22AM
09:42AM
09:57AM
10:12AM
09:29AM
09:44AM
09:58AM
10:14AM
10:28AM
Enabled
Enabled
Enabled
Enabled
Enabled
Clean Valves Operation
Tube Cleaning Delay 01:12
Tube Cleaning Valve Length 01:27
12:00
12:15
12:30
12:45
1:00
1:15
1:30
1:45
2:00
120
122
124
318
134
370
382
384
386
372
374
376
378
380
388
390
392
394
396

FIG. 25

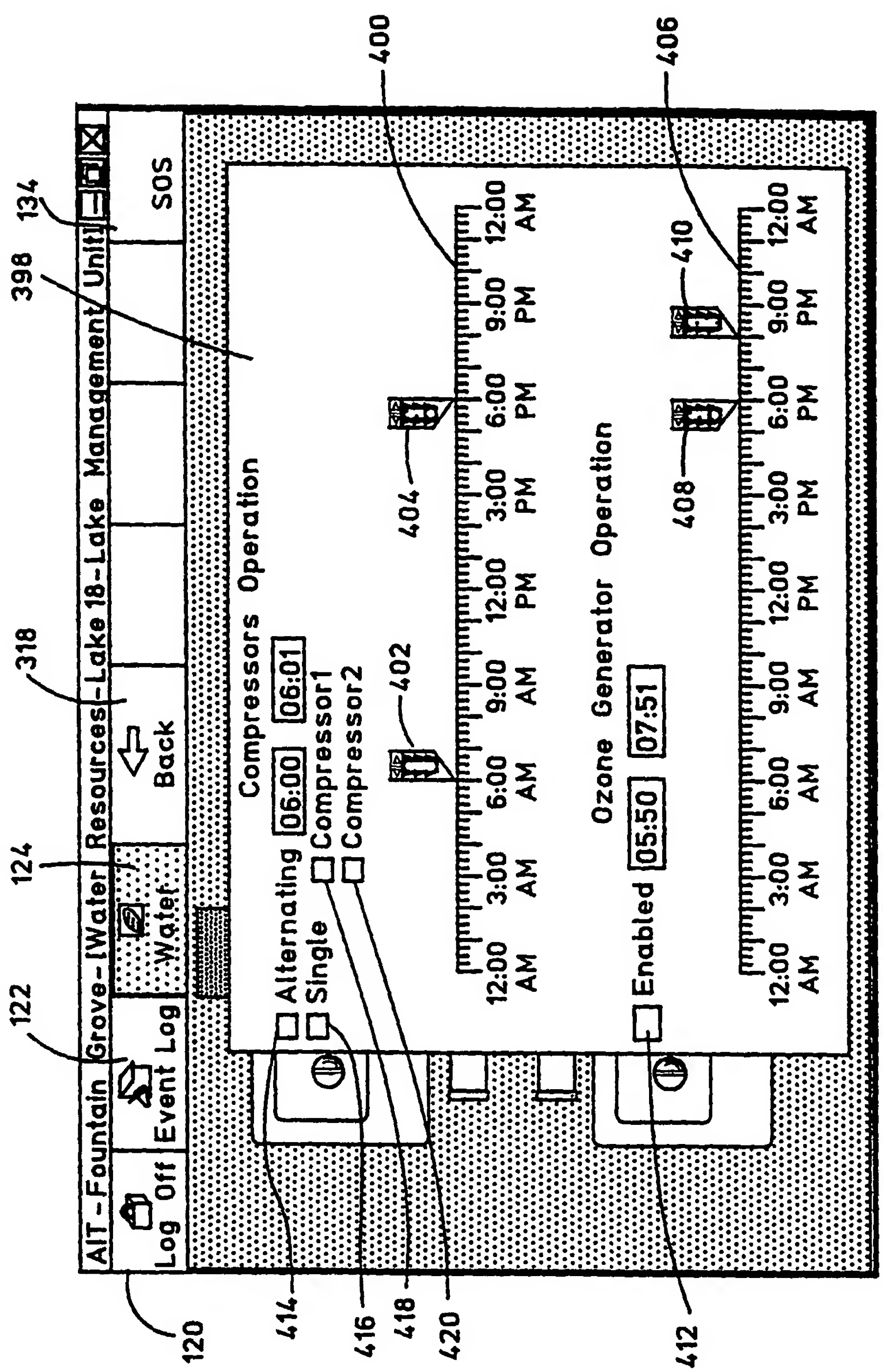
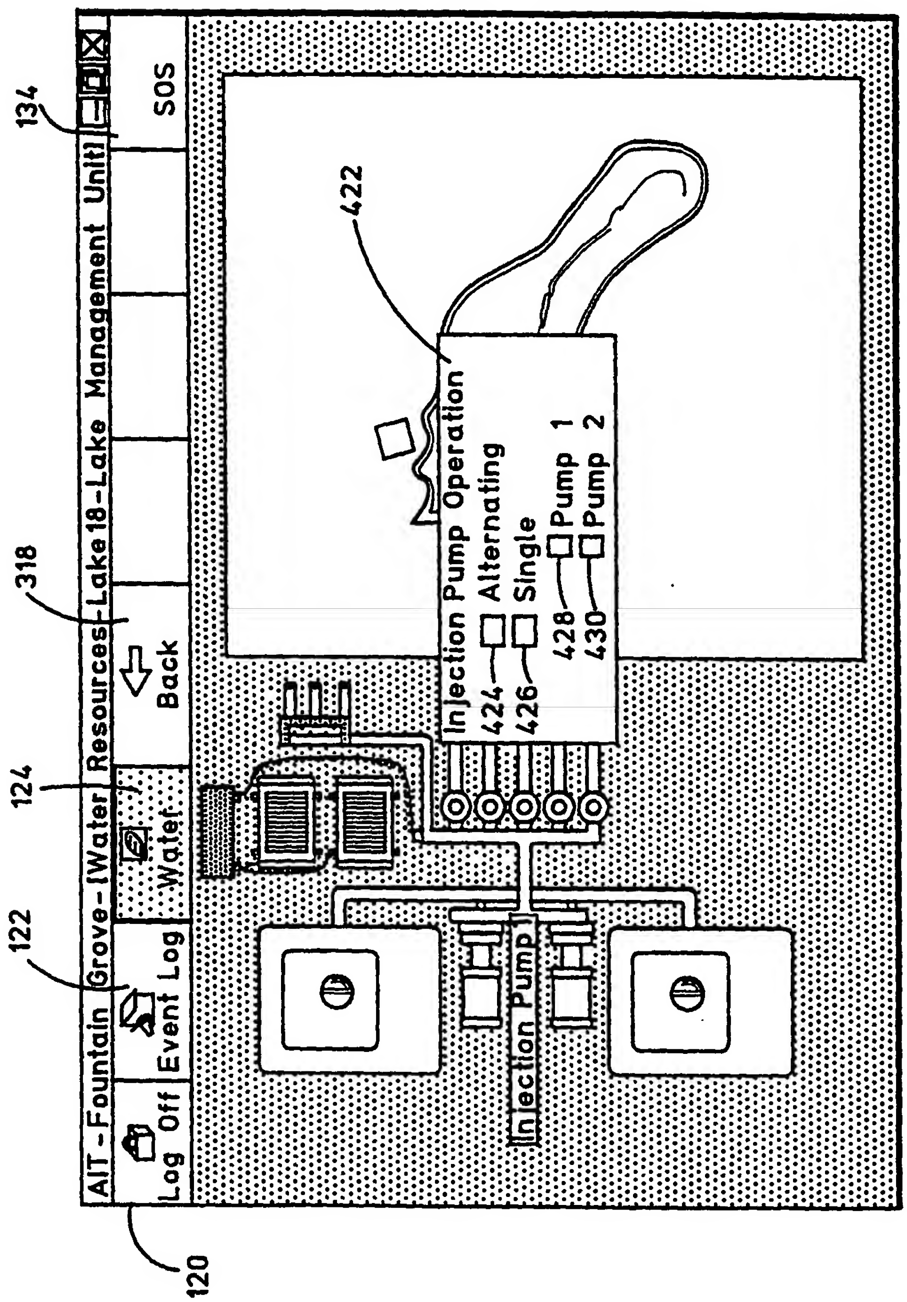

AIT-Fountain Grove-[Water Resources]-Lake 18-Lake Management Unit
Log Off
Event Log
Water
Back
SOS
Compressors Operation
Alternating
06:00
06:01
Single
Compressor1
Compressor2
12:00 AM
3:00 AM
6:00 AM
9:00 AM
12:00 PM
3:00 PM
6:00 PM
9:00 PM
12:00 AM
Ozone Generator Operation
Enabled
05:50
07:51
120
122
124
134
318
398
400
402
404
406
408
410
412
414
416
418
420

FIG. 26



AIT-Fountain Grove-[Water Resources-Lake 18-Lake Management Unit]
Log Off
Event Log
Water
Back
SOS
Injection Pump Operation
Alternating
Single
Pump 1
Pump 2
Injection Pump
134
318
124
122
120
422
424
426
428
430

FIG. 27

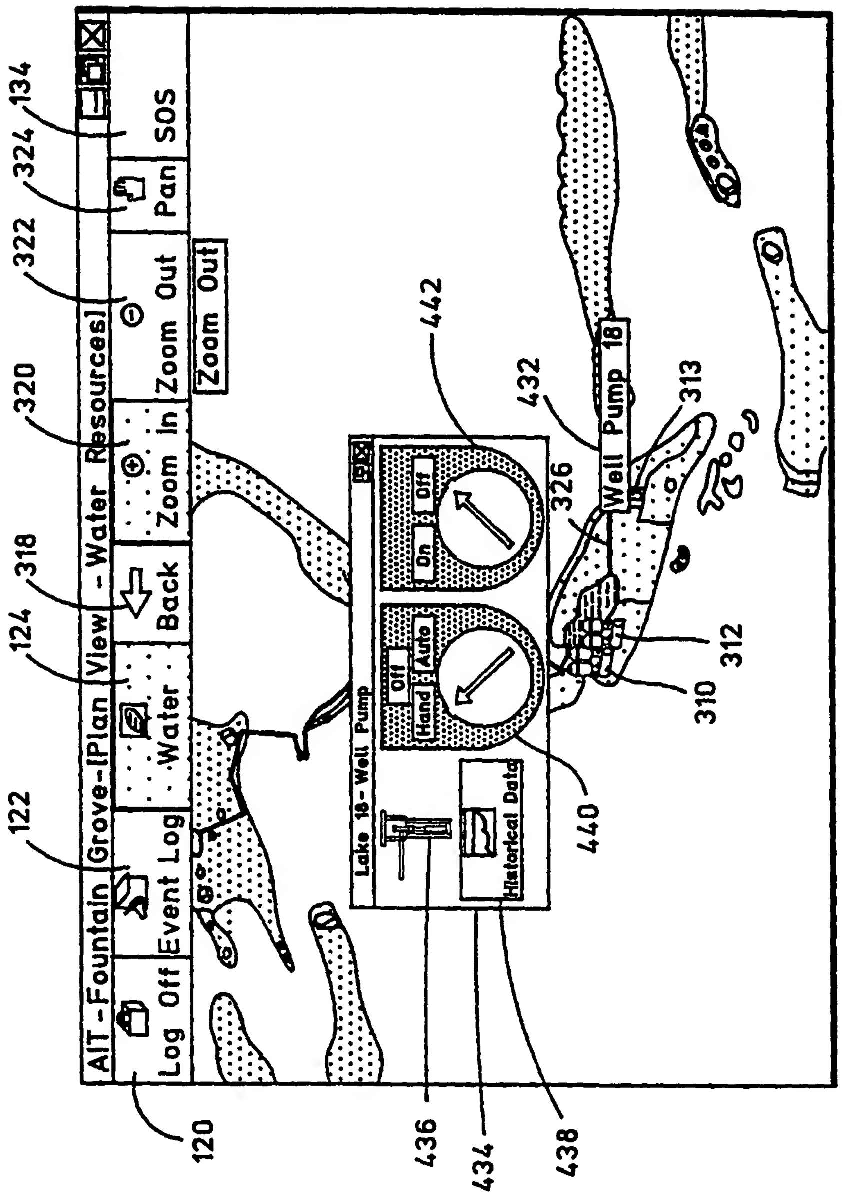

AIT-Fountain Grove-[Plan View - Water Resources]
Log Off
Event Log
Water
Back
Zoom In
Zoom Out
Pan
SOS
Zoom Out
Lake 18-Well Pump
Hand
Off
Auto
On
Off
Historical Data
Well Pump 18
120
122
124
318
320
322
324
134
442
432
313
326
312
310
440
436
434
438

FIG. 28

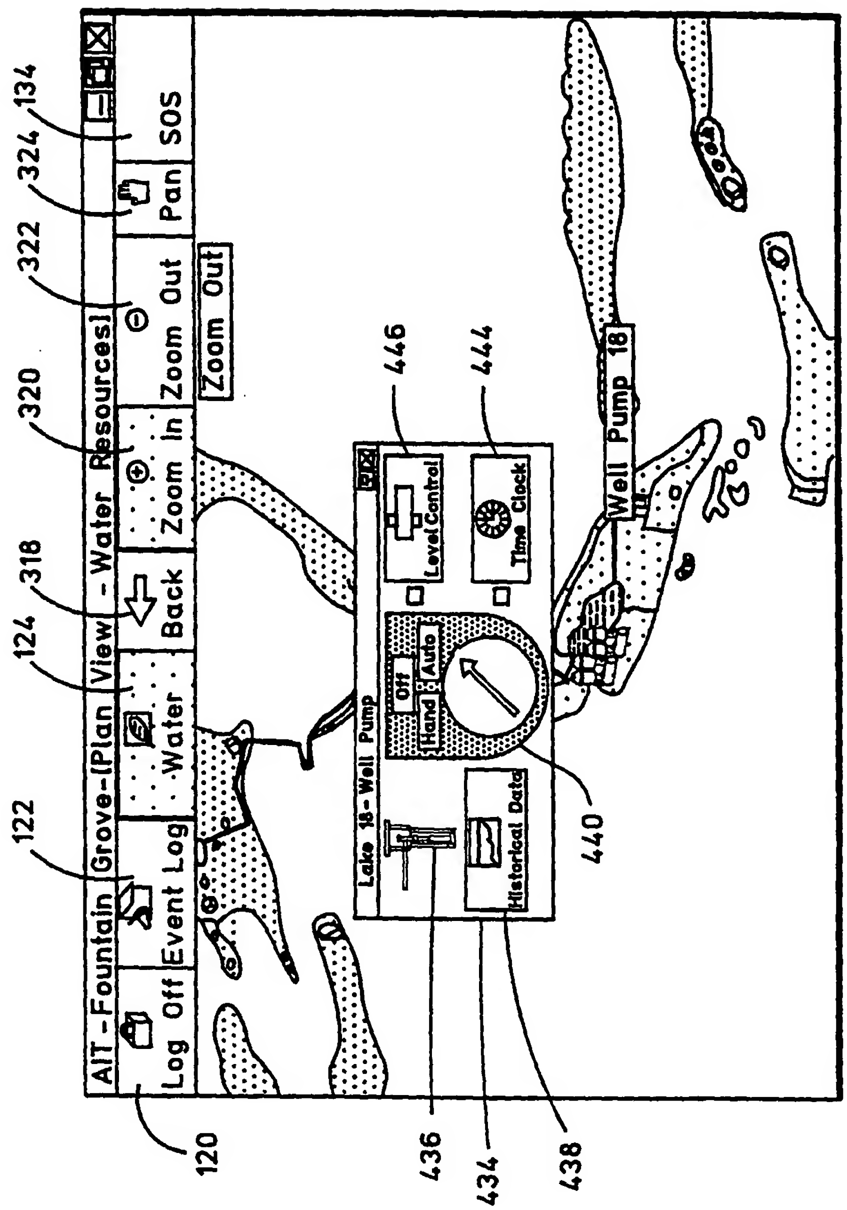

AIT - Fountain Grove-[Plan View - Water Resources]
Log Off
Event Log
Water
Back
Zoom In
Zoom Out
Pan
SOS
Zoom Out
Lake 18-Well Pump
Off
Hand
Auto
Level Control
Time Clock
Historical Data
Well Pump 18
120
122
124
318
320
322
324
134
446
444
440
436
434
438

FIG. 29

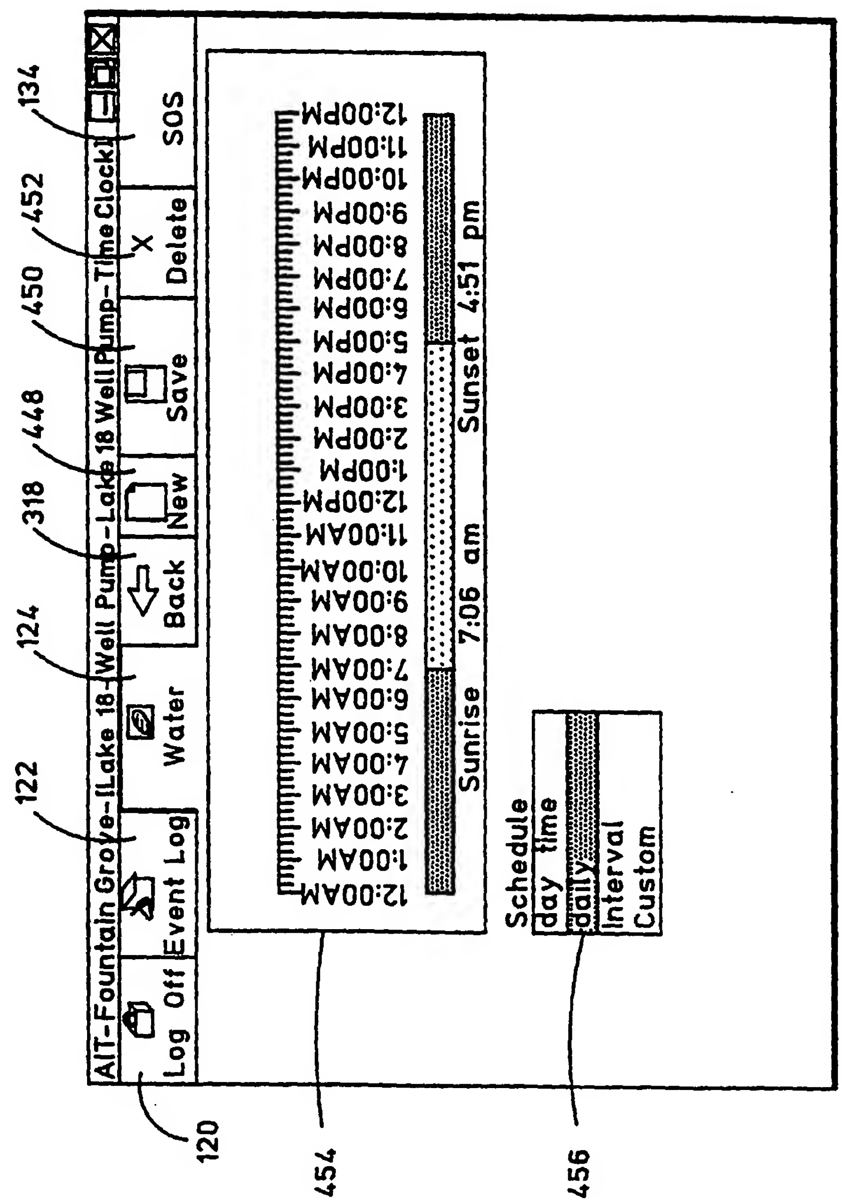

AIT-Fountain Grove-(Lake 18-Well Pump-Lake 18 Well Pump-Time Clock)
Log Off
Event Log
Water
Back
New
Save
Delete
SOS
12:00AM
1:00AM
2:00AM
3:00AM
4:00AM
5:00AM
6:00AM
7:00AM
8:00AM
9:00AM
10:00AM
11:00AM
12:00PM
1:00PM
2:00PM
3:00PM
4:00PM
5:00PM
6:00PM
7:00PM
8:00PM
9:00PM
10:00PM
11:00PM
12:00PM
Sunrise 7:06 am
Sunset 4:51 pm
Schedule
day time
daily
Interval
Custom
120
122
124
318
448
450
452
134
454
456

FIG. 30

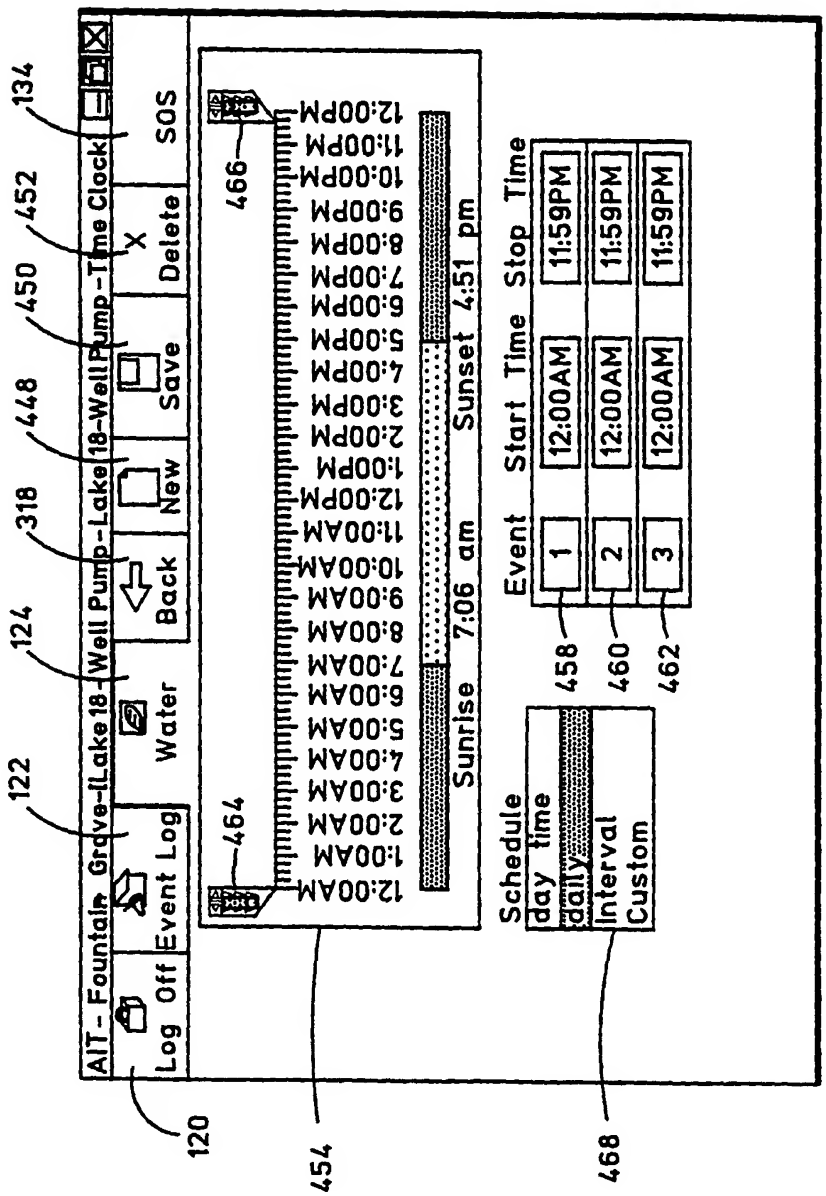

AIT- Fountain Grove-(Lake 18-Well Pump-Lake 18-Well Pump-Time Clock
Log Off
Event Log
Water
Back
New
Save
Delete
SOS
12:00AM
1:00AM
2:00AM
3:00AM
4:00AM
5:00AM
6:00AM
7:00AM
8:00AM
9:00AM
10:00AM
11:00AM
12:00PM
1:00PM
2:00PM
3:00PM
4:00PM
5:00PM
6:00PM
7:00PM
8:00PM
9:00PM
10:00PM
11:00PM
12:00PM
Sunrise 7:06 am
Sunset 4:51 pm
Schedule
day time
daily
Interval
Custom
Event
Start Time
Stop Time
1
2
3
12:00AM
11:59PM
120
122
124
318
448
450
452
134
454
464
466
458
460
462
468

FIG. 31

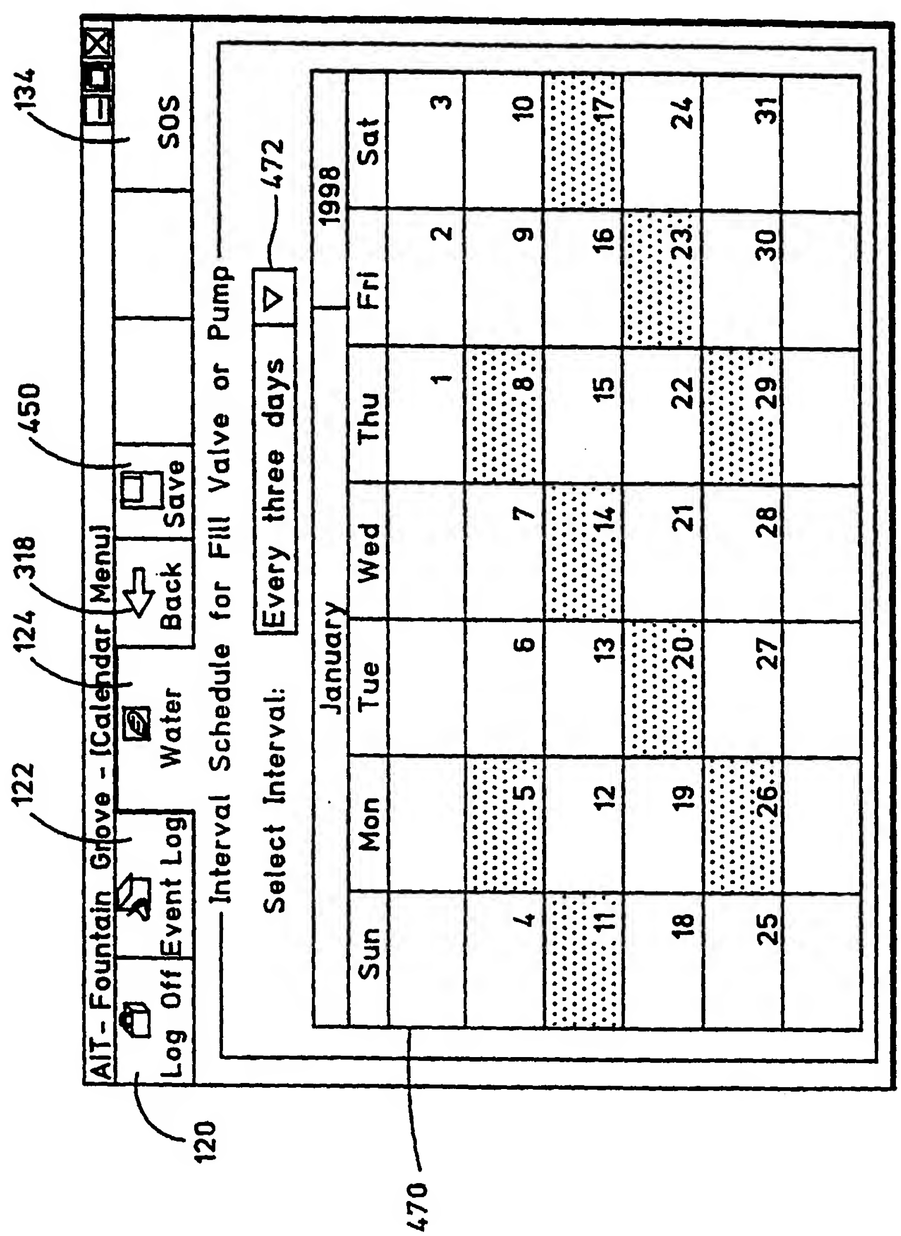

AIT - Fountain Grove - [Calendar Menu]
Log Off
Event Log
Water
Back
Save
SOS
Interval Schedule for Fill Valve or Pump
Select Interval:
Every three days
January
1998
Sun
Mon
Tue
Wed
Thu
Fri
Sat
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
120
122
124
318
450
134
472
470

FIG. 32

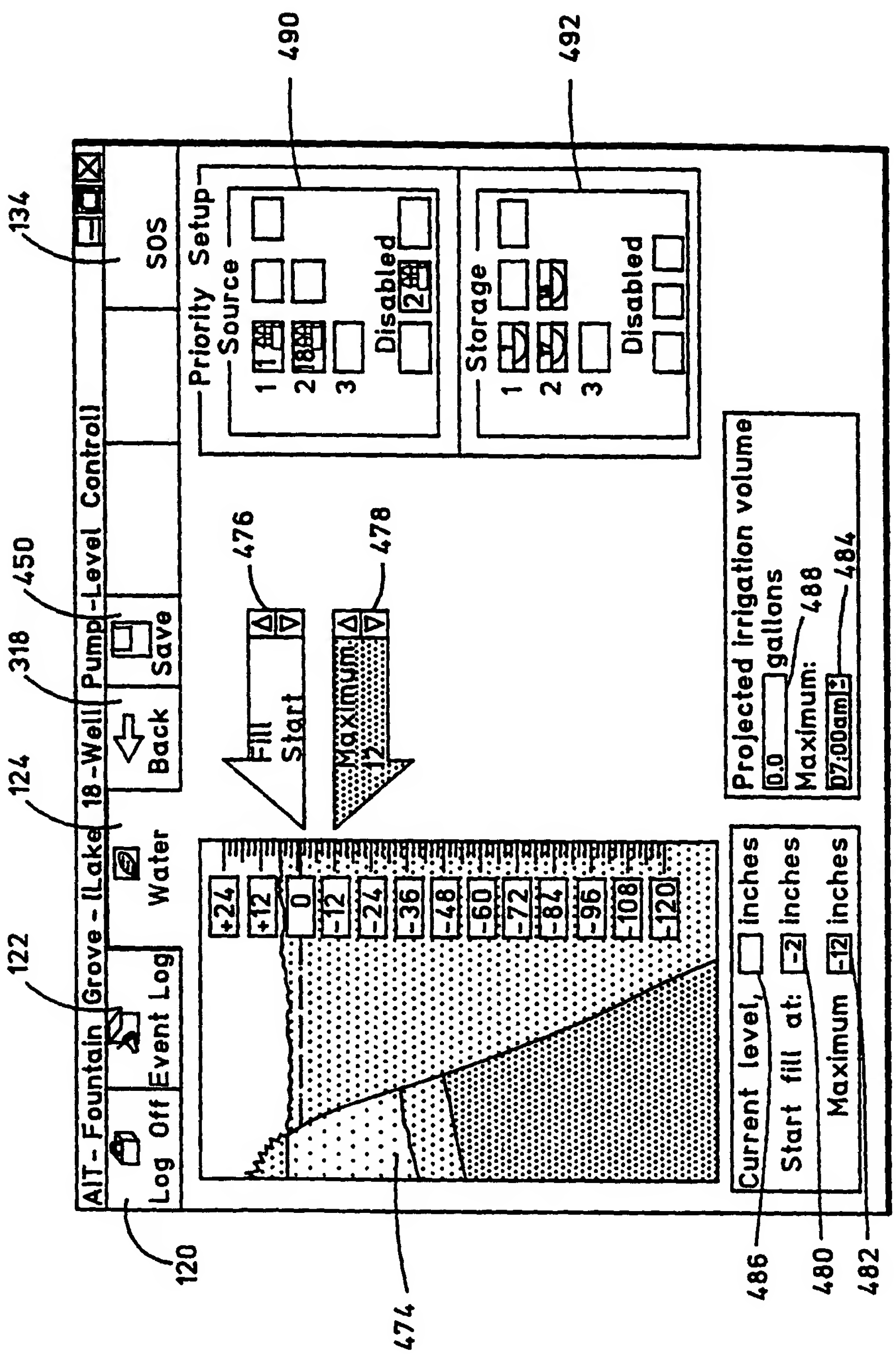

AIT- Fountain Grove - [Lake 18-Well Pump-Level Control]
Log Off
Event Log
Water
Back
Save
SOS
+24
+12
0
-12
-24
-36
-48
-60
-72
-84
-96
-108
-120
Fill Start
Maximum 12
Priority Setup
Source
1
2
3
Disabled
Storage
1
2
3
Disabled
Current level, inches
Start fill at: -2 inches
Maximum -12 inches
Projected irrigation volume
0.0 gallons
Maximum:
07:00am
134
124
122
318
450
120
474
476
478
490
492
486
480
482
488
484

FIG. 33

INTERNATIONAL SEARCH REPORT

Int tional Application No
PCT/US 99/02354

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 A01G25/16

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 A01G

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 246 164 A (MCCANN IAN R ET AL) 21 September 1993 see the whole document ---	1-3,9, 14,16, 19-21, 27,32, 34, 37-39, 45,50,52
A	WO 97 08942 A (SMART RAIN CORP INC ;GAGNON ROMAIN (CA)) 13 March 1997 see page 5, line 22 - page 6, line 18 ---	1-3,9, 14,16, 19-21, 27,32, 34, 37-39, 45,50,52

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
27 May 1999	04/06/1999

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Merckx, A

1

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	WO 86 05945 A (TOWNSEND CONTROLS PTY LTD) 23 October 1986	
A	US 5 479 339 A (MILLER RALPH W) 26 December 1995	

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

Int tional Application No
PCT/US 99/02354

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5246164 A	21-09-1993	WO 9501719 A	19-01-1995
WO 9708942 A	13-03-1997	US 5740031 A	14-04-1998
		AU 6867296 A	27-03-1997
		AU 6867496 A	27-03-1997
		WO 9709612 A	13-03-1997
		EP 0852459 A	15-07-1998
WO 8605945 A	23-10-1986	AU 5900286 A	05-11-1986
		EP 0220291 A	06-05-1987
		US 5025361 A	18-06-1991
US 5479339 A	26-12-1995	NONE	